

**Safety Evaluation Report for
10-160B Consolidated Safety Analysis Report
Addendum for Shipment of Gammacell Contents**

Docket No. 14-02-9204

Prepared by: James M. Shuler Date: APR 18 2014

James M. Shuler
Manager, DOE Packaging Certification Program
Office of Packaging and Transportation

Approved by: Stephen C. O'Connor Date: APR 18, 2014

Stephen C. O'Connor
Headquarters Certifying Official
Director, Office of Packaging and Transportation

SUMMARY

This Safety Evaluation Report (SER) documents the independent technical review by the Department of Energy (DOE) Packaging Certification Program (PCP) staff for compliance with 10 CFR Part 71 of the Addendum prepared and submitted by EnergySolutions (ES) for the Idaho National Laboratory (INL) to amend DOE Certificate of Compliance (CoC) Number 9204, Rev 6.

The contents requested by ES for shipment in the Model 10-160B Type B Radwaste Shipping Cask (10-160B) are ^{137}Cs and/or ^{60}Co sealed sources loaded in a Gammacell Irradiator Shielded Insert (GC) and cribbing placed within the 10-160B for transport.

The GC 200 and 220 are expired Type B(U) packaging designs. PCP reviewed three GC packaging configurations: GC 200, GC 200 with extra shielding band, and GC 220. Only one GC can be overpacked at a time in a 10-160B for shipment. A two-piece cribbing system was designed to minimize the movement of a GC within the 10-160B.

The 10-160B will be loaded at the Southwest Research Institute (SwRI) and shipped to the Nevada National Security Site (NNSS), where the GC will be removed for disposal.

The safety performance of a GC overpacked in the 10-160B with the contents, shipping configuration and conditions described in this SER, meet the applicable requirements of 10 CFR Part 71 and DOE CoC Number 9204, Revision 6.

1. GENERAL INFORMATION AND DRAWINGS

DOE PCP staff performed a review of the general information and drawings provided in the Addendum^[1] to DOE CoC 9204^[2] for compliance with 10 CFR Part 71.^[3] The review focused on a GC loaded with sealed ^{137}Cs and/or ^{60}Co sources and wooden cribbing as contents in the 10-160B.

The Applicant proposed the following items as authorized contents in the 10-160B:

- GC 200, GC 200 with extra shielding band, and GC 220 loaded with undamaged sealed metallic ^{137}Cs and/or ^{60}Co sources in source containers, and
- Wooden cribbing.

Each GC consists of a lead-shielded, cylindrical, steel-encased body welded to a support frame. The overall height of a GC is approximately 34 inches. The GC 200 is 25 $\frac{3}{4}$ -inches in diameter with approximately 9 inches of shielding thickness. The GC 200 with extra shielding band is 28 inches in diameter and has an additional 1 inch thick band of lead added to the side of the packaging. The GC 220 is 30 inches in diameter with approximately 14 inches of shielding thickness.

The GC 200 Irradiator and 220 Irradiator designs were previously licensed by the U.S. Department of Transportation for Type B(U) under Competent Authority Certificates (CAC)

USA/6352/B(U) and USA/6352/B(U), respectively. After expiration of the CACs, the GC packagings were modified by SwRI to accept multiple pencil sources and/or teletherapy sources in their respective inner cavities. The GC modifications are described in Section 1.1.1 of the Addendum and illustrated in Figure 1-4 and Drawings in the Addendum.

The components of the modified GCs are as follows: a) shielded body with integral skid, b) top shield plug/lid, c) lower shield plug, and d) source containers (i.e., bucket and spacers/plate configurations). The usable cavity in the GC 200 and 200 with extra shielding band is 6.2 inches tall by 7 inches in diameter; the usable cavity in the GC 220 is 8.5 inches tall by 8.75 inches in diameter. Source containers are designed to fit these respective cavities; there are two source container configurations for the GC 200 and 200 with extra shielding band and two for the GC 220.

Sources or sources containers are remotely handled by manipulators to load into the GC. The two source container configurations for the GC 200 and 200 (with the extra shielding band) are: 1) a steel bucket, or 2) steel spacer and tungsten plate. Sources are placed in the steel bucket and then loaded remotely into the GC, or the steel spacer and tungsten plate are preloaded in the GC, and then sources are remotely loaded in the container. The source containers for the GC 220 are: 1) a steel bucket and thick outer spacer, or 2) a carousel, thin inner spacer and bucket. The outer spacer is preloaded in the GC and then a steel bucket with sources is loaded remotely into the GC; or a carousel and thin inner spacer are preloaded in the GC, sources are then remotely loaded one-by-one into the carousel, and then a bucket is loaded with sources inside the inner spacer. The top/shield plug/lid is remotely placed in the GC body after the loading operation. The upper shield plug/lid of the GC 200 (both configurations) is secured to the GC body with eight (8) 3/4-inch-10 bolts, and the GC 220 upper shield plug/lid is secured to the body with four (4) 3/4-inch-10 bolts. All bolts are torqued to a minimum of 50 ft-lb.

The radioactive content and thermal limits for GCs are listed in Table 1. Note: A combination of ¹³⁷Cs and/or ⁶⁰Co sources may be loaded within the same GC, provided that the total wattage does not exceed the thermal limit for the respective GC configuration.

Table 1. GC Radioactive and Thermal Limits

GC Configuration	¹³⁷ Cs (Ci)	⁶⁰ Co (Ci)	¹³⁷ Cs and ⁶⁰ Co (Ci)	Thermal limit (watts)
200 Irradiator	27,000	9,000	-	138.5
200 Irradiator w/extra shielding band				
220 Irradiator	40,000	13,000	-	200

The wooden cribbing design is essential to maintain the position of a GC within the 10-160B and for structural protection of the package.

The maximum weight of the contents is less than 10,000 lb., which is less than the 14,250 lb. maximum content weight limit for the package.

The Criticality Safety Index (CSI) is zero, which is the same as presented in the Consolidated Safety Analysis Report (CSAR).^[4]

Based on the PCP staff review of the statements and representations in the Addendum, PCP concludes the addition of these contents have no impact on the safety performance of the 10-160B. The requirements of 10 CFR Part 71 for normal conditions of transport (NCT) and hypothetical accident conditions (HAC) are satisfied, provided that the GC and cribbing configuration are loaded in the 10-160B as described and evaluated in the Addendum.

2. STRUCTURAL

PCP staff performed a review of the structural evaluation in the Addendum for compliance with 10 CFR Part 71. The review focused on the structural interactions of a GC loaded with ¹³⁷Cs and/or ⁶⁰Co sealed sources and wooden cribbing as contents in the 10-160B.

Radioactive sealed sources are confined within a GC in a source container configuration. The GC is enclosed with a two-piece wood cribbing structure sized to fit within the 10-160B. The cribbing is constructed of common white pine (or similar) lumber, in combinations of both plywood and planks. The cribbing is used as a compression-only component, with the credited wood strength ranging from minimum to maximum expected values for each load/wood orientation condition being evaluated.

The maximum weight of the contents (GC + cribbing) evaluated in the Addendum, and listed in Table 2, is less than 10,000 lb., which is less than the 10-160B maximum content weight of 14,250 lbs.

Table 2. Content Weight

GC Configuration	Weight (lb)
200 Irradiator	5,205
200 Irradiator w/extra shielding band	6,118
220 Irradiator	7,501
Cribbing	1,352

The Applicant performed a lifting analysis of the slings and hoist rings for loading the contents (GC plus cribbing) in the 10-160B and evaluated the wood screws used to fasten the layers of cribbing together to confirm the appropriate lifting safety factors.

The Addendum contents were evaluated by calculation to determine compliance with the 10-160B CoC and CSAR and to verify that the credited structural features are captured on the fabrication drawings. The CSAR provided evaluation of the 10-160B package for HAC free-

drop test with a 14,500 lb. generic content. The Addendum content (GC plus cribbing) is less than 10,000 lb.; therefore, the Addendum content is bounded by the CSAR evaluation.

The combined effect of the cribbing size and stiffness was reviewed by PCP staff for compliance with the existing CSAR analysis. The integrity of the contents was reviewed to establish essentially no damage under NCT and that the credited damage state for HAC was within defensible capacities of the cribbing and GC. PCP staff checked the Addendum calculations to ensure acceptable package performance for the potential range of material properties associated with the materials of construction. This review included coordination with Addendum Chapters 4 and 5 to ensure consistency between the calculated and credited post-NCT/HAC damage states.

GC closure bolts, welds, upper and lower shield plugs, and cribbing were evaluated for NCT. These components were unaffected by end, side and corner drops from a distance of one foot. The cribbing was undamaged to the degree that the 10-160B continued to perform its safety function under HAC free-drop conditions.

The effects of a HAC 30-ft. free drop of the 10-160B in end-drop orientations of all GC configurations was analyzed in the Addendum to confirm:

- a) The adequacy of the cribbing design (i.e., crush depth) to prevent the GC from damaging the 10-160B,
- b) Skin thickness of the GC to resist penetration from the cribbing,
- c) No significant lead slump in the GC,
- d) Minimum thickness of source container configurations to prevent buckling,
- e) Minimum thickness of tungsten plate for shielding, and
- f) Minimum thickness of the pallet-to-GC and lid plug welds.

The GC closure bolts were evaluated for tensile loads, head shear, and minimum thread engagement for the HAC drop.

Staff performed a confirmatory analysis of the cribbing material to verify the calculations for wood-crush magnitudes. The Addendum calculations relied on empirical equations based on tests conducted on similar softwoods, but not specifically pine. PCP staff's confirmatory analysis was based on a more rigorous method, employing actual crush strength data, which included southern, western, and eastern pines, with strengths listed parallel, perpendicular, and traverse to the wood grain.

Based on the PCP staff review of the statements and representations in the Addendum, PCP concludes that the addition of these contents has no adverse impact on the safety performance of the 10-160B. The requirements of 10 CFR Part 71 for NCT and HAC are satisfied, provided that the GC and cribbing configuration are loaded in the 10-160B as described and evaluated in the Addendum.

3. THERMAL

PCP staff performed a review of the thermal evaluation in the Addendum for compliance with 10 CFR Part 71. The review focused on the pressurization in the packaging from the GC loaded with ^{137}Cs and/or ^{60}Co sealed sources and wooden cribbing as contents in the 10 160B.

The Addendum content limits (see SER Table 1) do not exceed the CSAR limit of 200 watts.

The Applicant analyzed hydrogen gas generation and pressure buildup in the 10-160B by calculation. Hydrogen gas is generated by radiolysis in the cavity of the 10-160B due to gamma energy deposition in the wood cribbing. The GCs are not sealed and do not contain hydrogenous material; thus the wood cribbing is the sole source of hydrogen. The calculated time to reach 5 volume percent (vol. %) hydrogen in the 10-160B cavity for the Addendum contents is 2,464 years.

The Applicant calculated a maximum NCT pressure of 3.89 psig, which is below the 31.2 psig pressure limit listed in the CSAR. For HAC, the maximum pressure was determined to be 6.76 psig, which is below the 94.3 psig CSAR limit.

Based on the PCP staff review of the statements and representations in the Addendum, PCP concludes that the addition of these contents has no adverse impact on the safety performance of the 10-160B. The requirements of 10 CFR Part 71 for NCT and HAC are satisfied, provided that the GC and cribbing configuration are loaded in the 10-160B as described and evaluated in the Addendum.

4. CONTAINMENT

PCP staff performed a review of the containment evaluation in the Addendum for compliance with 10 CFR Part 71. The review focused on the packaging from the GC loaded with ^{137}Cs and/or ^{60}Co sealed sources and wooden cribbing as contents in the 10-160B.

The GC does not include a containment system.

The A_2 values in Table 4.1 of the Addendum for GC contents range from 833 to 2,500. The CSAR uses $3,000A_2$ for the leakage rate evaluation in CSAR Sections 4.2 and 4.3; therefore, the Addendum contents are bounded by the CSAR containment analysis and CoC Section 5(b)(2)(i).

Based on the PCP staff review of the statements and representations in the Addendum, PCP concludes that the addition of these contents has no adverse impact on the safety performance of the 10-160B. The requirements of 10 CFR Part 71 for NCT and HAC are satisfied, provided that the GC and cribbing configuration are loaded in the 10-160B as described and evaluated in the Addendum.

5. SHIELDING

PCP staff performed a review of the shielding evaluation in the Addendum for compliance with 10 CFR Part 71. The review focused on the packaging from the GC loaded with ^{137}Cs and/or ^{60}Co sealed sources and wooden cribbing as contents in the 10-160B.

The 10-160B with Addendum contents will be shipped "Exclusive use" as defined in 10 CFR 71.4. The Addendum analysis compared the dose rates from the contents to the limits in 10 CFR 71.47(b) and 10 CFR 71.51 for NCT and HAC.

The contents in the GCs range from 9,000 to 40,000 curies. The Applicant performed a shielding analysis of the Addendum contents in the 10-160B for NCT and HAC by computer model (MCNP5).

Table 5-1 in the Addendum summarizes the NCT dose rates for the 10-160B loaded with the GC 200, 200 (extra shielding band), or GC 220 with various inner bucket configurations. A single case of the GC 200 was performed without an inner bucket. The maximum NCT dose rates from this case are 6 mrem/hr. at contact on the bottom of the 10-160B and 1.72 mrem/hr. at 2 meters from the base of the 10-160B. The maximum dose rates of the GC 220 with steel bucket are 3.4 mrem/hr. at contact on the bottom of the 10-160B and 0.25 mrem/hr. at 2 meters from the base of the 10-160B. The maximum NCT dose rates for this content in the 10-160B are within the allowable limits of 10 CFR 71.47(b).

Table 5-2 in the Addendum summarizes the dose rates for HAC with the GC positioned in the worst-case geometric configuration following an accident. HAC models assume a) loss of wood cribbing, b) the GCs relocate to the bottom or top of the 10-160B cavity, c) loss of source containers, d) collapse of source material to form a 1-cm "point source", e) the "point source" relocates directly above or below the maximum gaps around the lower plug and top plug, and f) source material as air or void space to eliminate self-shielding. The maximum dose rates are determined at the outside lower surface of the 10-160B base, which bounds the 1-meter dose rates. The maximum HAC dose rate of 834.7 mrem/hr. at contact was based on the GC 200 positioned at the bottom of the 10-160B cavity. The maximum HAC dose rate for this content in the 10-160B is within the allowable limit of 10 CFR 71.51.

The energy deposition rate from contents to the wood cribbing was used to calculate the time to reach 5 vol% hydrogen in the 10-160B cavity.

Based on the PCP staff review of the statements and representations in the Addendum, PCP concludes that the addition of these contents has no adverse impact on the safety performance of the 10-160B. The requirements of 10 CFR Part 71 for NCT and HAC are satisfied, provided that the GC and cribbing configuration are loaded in the 10-160B as described and evaluated in the Addendum.

6. CRITICALITY

PCP staff performed a review of the criticality evaluation in the Addendum for compliance with 10 CFR Part 71. The review focused on the packaging from the GC loaded with ^{137}Cs and/or ^{60}Co sealed sources and wooden cribbing as contents in the 10-160B.

The Addendum contents do not contain fissionable material; therefore, there are no packaging and transportation safety concerns with respect to criticality.

Based on the PCP staff review of the statements and representations in the Addendum, PCP concludes that the addition of these contents has no adverse impact on the safety performance of the 10-160B. The requirements of 10 CFR Part 71 for NCT and HAC are satisfied, provided that the GC and cribbing configuration are loaded in the 10-160B as described and evaluated in the Addendum.

7. PACKAGE OPERATIONS

PCP staff performed a review of the package operations evaluation in the Addendum for compliance with 10 CFR Part 71. The review focused on the packaging from the GC loaded with ^{137}Cs and/or ^{60}Co sealed sources and wooden cribbing as contents in the 10-160B.

The procedures for loading and unloading the Gammacell and cribbing were reviewed by staff.

Based on the PCP review of the statements and representations in the Addendum, PCP concludes that the addition of these contents has no adverse impact on the safety performance of the 10-160B. The requirements of 10 CFR Part 71 for NCT and HAC are satisfied, provided that the GC and cribbing configuration are loaded in the 10-160B as described and evaluated in the Addendum and Operating Procedures in Chapter 7 of the CSAR.

8. ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

PCP staff performed a review of the acceptance tests and maintenance evaluation in the Addendum for compliance with 10 CFR Part 71. The review focused on the packaging from the GC loaded with ^{137}Cs and/or ^{60}Co sealed sources and wooden cribbing as contents in the 10-160B.

There are no additional acceptance tests and maintenance activities required for the 10-160B for this Addendum to the CSAR.

The GCs are single-use containers; therefore, there are no routine or periodic maintenance activities.

PCP staff reviewed the acceptance test requirements for the GCs and components. The GCs and components are visually examined for adverse conditions in materials or fabrication. All ferromagnetic material welds are inspected per ASME Code, Section III, Div. I, Subsection NF, NF-5230 for Class 3 support attachments, and Section V, Article 7 for magnetic particle (MT)

examinations, and Section V, Article 6 for liquid penetrant (PT) examinations. Acceptance standards are per ASME Section III, Div. I, Subsection NF, NF-5340 and NF-5350, as appropriate.

The lifting attachments (lift lugs) and load carrying components (lid fasteners) will be tested equal to 150% of rated load capacity.

To assure that the package is free of stream paths in the shield exceeding allowable transportation limits, shielding integrity of the GCs will be verified by gamma scan after they are loaded but prior to moving them out of the hot cell and accepting them for shipment. All gamma scanning will be performed on a 4-inch square or less grid system. The acceptance criteria will be that voids resulting in shield loss in excess of 10% of the normal lead thickness in the direction measured shall not be acceptable. If shielding integrity test is deemed unacceptable, the GC shall be rejected and cannot be used for transport.

Based on the PCP staff review of the statements and representations in the Addendum, PCP concludes that the addition of these contents has no adverse impact on the safety performance of the 10-160B. The requirements of 10 CFR Part 71 for NCT and HAC are satisfied, provided that the GC and cribbing configuration are accepted and loaded in the 10-160B as described and evaluated in the Addendum.

9. QUALITY ASSURANCE

PCP staff performed a review of the quality assurance (QA) evaluation in the Addendum for compliance with 10 CFR Part 71, Subpart H. The review focused on the packaging from the GC loaded with ^{137}Cs and/or ^{60}Co sealed sources and wooden cribbing as contents in the 10-160B.

The Addendum supplements the QA requirement for the 10-160B, for the GCs and components.

The roles and responsibilities of the organizations performing QA related activities are defined in the Addendum, Section 9.3.1.

The Quality Levels of the GCs and components are defined in Addendum, Table 9-2b.

Based on the PCP review of the statements and representations in the Addendum, PCP concludes that the addition of these contents has no adverse impact on the safety performance of the 10-160B. The requirements of 10 CFR Part 71, Subpart H, are satisfied, provided that the GC and cribbing configuration are designed, fabricated, procured, used, maintained and loaded in the 10-160B as described and evaluated in the Addendum.

REFERENCES

- [1] *Gammacell 200, Gammacell 200 (Extra Shielding Band) and Gammacell 220 Inserts Addendum for Model 10-160B Type B Radwaste Shipping Cask*, Revision 1, February 28, 2014
- [2] DOE Certificate of Compliance, Certificate Number 9204, Revision 6.

- [3] Title 10, Code of Federal Regulations, Part 71 (10 CFR 71), Packaging and Transportation of Radioactive Materials
- [4] *Consolidated Safety Analysis Report For Model 10-160B Type B Radwaste Shipping Cask*, Revision 4, July 2012. As amended by revised Chapter 7 submitted to NRC on July 26, 2012, and by drawing DWG-CSK-12CV01-EG-0002-01, Rev 3 "Cask Secondary Lid Thermal Shield Details submitted to NRC on August 26, 2012