ENERGYSOLUTIONS

10 August 2012
EL&P-028-12

Mr. Pierre Saverot
Licensing Branch
Division of Spent Fuel Storage and Transportation
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555

SUBJECT: Amendment Request for Certificate of Compliance No. 9168 for the Model 8-120B Package - Supplemental Information
Docket No. 71-9168
TAC No. L24549

Dear Mr. Saverot:

Energy*Solutions* provides the attached 8-120B Safety Analysis Report (SAR) revisions, drawings, and references as replacement information to our amendment request of July 20th. The changes address the issues that have been the subject of several recent emails and discussions.

The SAR changes are found in the Table of Contents, description (Chapter 1), shielding (Chapter 5 and reference calculation), operations (Chapter 7), and maintenance chapter (Chapter 8). The drawings of the cask and thermal shield are revised. The references have been revised in electronic format to meet the NRC electronic document criteria. Please replace the items in the July 20th submittal with those in attached in this submittal.

Since this package provides unique capabilities in support of both commercial and governmental nuclear facilities, we request completion of the review of this supplemental information as soon as possible with issue of the revised certificate by August 23, 2012.

Should you or members of your staff have questions about this supplemental information, please contact me at mswhittaker@energysolutions.com or Mirza Baig at mibaig@energysolutions.com.

Sincerely,

Mark Whittaker
Sr. Health Physicist, Radiological Services

Attachments:

- Revised SAR TOC, Chapters 1, 5, 7, and 8
- Drawings
  - C-110-E-0007, Rev. 18 – 8-120B Shipping Cask (Non-Public)

NMSS24

  - DWG-CSK-12CV01-EG-0001, Rev. 3 – 8-120B Cask Secondary Lid Thermal-Shield
- Public Reference Documents
  - ST-626 Rev 0
  - ST-627 Rev 1
  - ST-608 Rev 0
  - ST-637 Rev 0
  - ST-635 Rev 0
  - ST-679 Rev 0
  - TH-027 Rev 2
  - TH-028 Rev 2
  - ST-0001 Rev 0 and Data
  - TH-0001 Rev 1 and Data
  - TH-0002 Rev 3 and Data
- Non-Public Reference Documents
  - ST-551, Rev. 3
  - ST-625 Rev. 0
  - ST-596 Rev. 1
  - ST-618 Rev. 1
  - NU-391 Rev. 5 and Data
  - Proprietary Affidavit

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1.0 General Information

1.1 Introduction

This Safety Analysis Report describes a reusable shipping package designed to protect radioactive material from both normal conditions of transport and hypothetical accident conditions. The package is designated the Model 8-120B package.

1.2 Package Description

1.2.1 Packaging

The package consists of a steel and lead cylindrical shipping cask with a pair of cylindrical foam-filled impact limiters installed on each end. The package configuration is shown in Figure 1-1. The internal cavity dimensions are 61 $\frac{13}{16}$ inches in diameter and 74 ⅞ inches high. The cylindrical cask body is comprised of a 1½ inch thick external steel shell and a ¾ inch internal steel shell. The annular space between the shells is filled with 3.35 inch thick lead. The base of the cask consists of two 3¼ inch thick flat circular steel plates. The cask lid consists of two 3¼ inch thick flat circular steel plates. The lid is fastened to the cask body with twenty 2-8 UN bolts. There is a secondary lid in the middle of the primary lid. This secondary lid is attached to the primary lid with twelve 2-8 UN bolts. A thermal shield protects the secondary lid. The thermal-shield consists of two polished stainless-steel plates that are separated by a thin air gap with stand-offs which provide an additional air gap above the secondary lid. The thermal-shield assembly is attached to the secondary lid lifting lugs with hitch-pins.

The impact limiters are 102 inches in outside diameter and extend 22 inches beyond each end of the cask. There is a 50.0 inch diameter void at each end. Each impact limiter has an external shell, fabricated from ductile low carbon steel, which allows it to withstand large plastic deformations without fracturing. The volume inside the shell is filled with a crushable shock and thermal insulating polyurethane foam. The polyurethane is sprayed into the shell and allowed to expand until the void is completely filled. The foam bonds to the shell, which creates a unitized construction for the impact limiters.

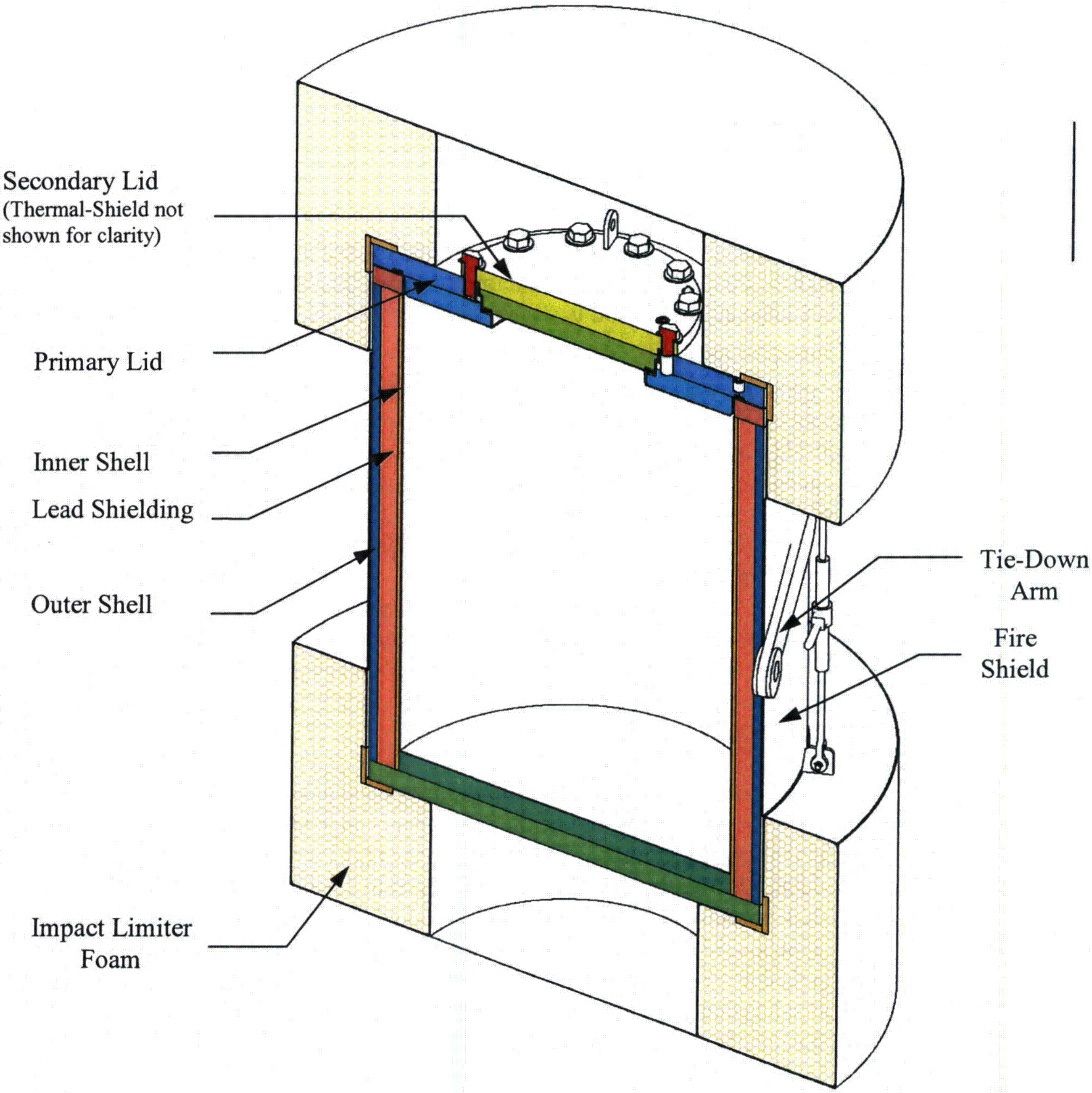


Figure 1-1
Features of the 8-120B Cask

The properties of the foam are further described in Section 2.2. The top and bottom impact limiters are connected together by eight one-inch diameter ratchet binders. This serves to hold the impact limiters in place on the cask during shipment, while allowing easy removal of the impact limiters for loading and unloading operations.

A general arrangement drawing of the package is included in Appendix 1.3. It shows the package dimensions as well as all materials of construction.

1.2.1.1 Containment Vessel

The containment vessel is defined as the inner steel shell of the cask body together with closure features comprised of the lower surface of the cask primary lid and 20 equally spaced 2-8 UN closure bolts and the lower surfaces of the cask secondary lid and the 12 equally spaced 2-8 UN closure bolts.

1.2.1.2 Neutron Absorbers

There are no materials used as neutron absorbers or moderators in the package.

1.2.1.3 Package Weight

Maximum gross weight for the package is 74,000 lbs. including a maximum payload weight of 14,430 lbs.

1.2.1.4 Receptacles

There are no receptacles on this package.

1.2.1.5 Vent, and Test Ports

Pressure test ports with manual venting features exist between the twin o-ring seals for both the primary and secondary lids. This facilitates leak testing the package in accordance with ANSI N14.5.

The vent port is provided with the same venting features for venting pressures within the containment cavity, which may be generated during transport, prior to lid removal. Each port is sealed with an elastomer gasket. Specification information for all seals and gaskets is contained in Chapter 4.

1.2.1.6 Lifting Devices

Lifting devices are a structural part of the package. From the General Arrangement Drawing shown in Appendix 1.3, it can be seen that two removable lifting ears are provided, which attach to the cylindrical cask body. Three lifting lugs are also provided for removal and handling of the lid. Similarly, three lugs are provided for removal and handling of the secondary lid. Refer to Section 2.5.1 for a detailed analysis of the structural integrity of the lifting devices.

1.2.1.7 Tie-downs

From the General Arrangement Drawing, shown in Appendix 1.3, it can be seen that the tie-down arms are an integral part of the external cask shell. Consequently, tie-down arms are considered a structural part of the package. Refer to Section 2.5.2 for a detailed analysis of the structural integrity of the tie-down arms.

1.2.1.8 Heat Dissipation

There are no special devices used for the transfer or dissipation of heat.

1.2.1.9 Coolants

There are no coolants involved.

1.2.1.10 Protrusions

There are no outer or inner protrusions except for the tie-down arms described above. Lifting lugs are removed prior to transport.

1.2.1.11 Shielding

Cask walls provide a shield thickness of 3.35 inches of lead and 2¼ inches of steel. Cask ends provide a minimum of 6½ inches of steel. The contents will be limited such that the radiological shielding provided (4½ inches lead equivalent) will assure compliance with DOT and IAEA regulatory requirements.

1.2.1.12 Configurations

There are three configurations of the 8-120B cask.

- Configurations 1 and 2 were fabricated per the previously approved drawing Rev. 13 and differ mainly in the

inclusion (Configuration 1) or lack (Configuration 2) of the optional drain port. Configuration 1 now includes sealing the drain port with the insertion and welding of a rod in the drain port. Acceptance Testing of Configurations 1 and 2 are described in Section 8.1. Fabrication of Configurations 1 or 2 after April 1, 1999 are not permitted.

- Configuration 3 does not have a drain port and the base plate is fabricated differently than Configurations 1 and 2. Acceptance Testing of Configuration 3 is described in Section 8.2.
- Configurations 1, 2 and 3 have the same Operations and Maintenance requirements and are described in Sections 7.0 and 8.3 respectively

All configurations have the same structural, thermal, containment, shielding, and criticality evaluations.

1.2.2 Contents of Packaging

1.2.2.1 Type form of material:

(1) Byproduct, source, or special nuclear material, in the form of dewatered resins, solids, including powdered or dispersible solids, or solidified material, contained within secondary container(s); or
(2) Radioactive material in the form of neutron activated metals or metal oxides in solid form contained within secondary container(s).

1.2.2.2 Maximum quantity of material per package:

Type B quantity of radioactive material not to exceed $3000A_2$, 200 thermal watts, and 14,430 pounds including weight of the contents, secondary container(s) and shoring. The contents may include fissile materials provided at least one of the paragraphs (a) through (f) of 10 CFR 71.15 is met. Materials producing more than 1×10^5 neutrons/sec in the total contents, other than fissile materials as allowed in the preceding sentence, are not authorized.

The activity of beta and gamma emitting radionuclides shall not exceed the limit determined per the procedure in Chapter 7 Attachment 1.
Powdered or dispersible solid radioactive materials must have a mass of at least 60 grams or a specific activity of 50 A_2/g or less.

1.2.2.3 Loading Restrictions

Contents shall be packaged in secondary containers. Except for close fitting contents, shoring must be placed between the secondary containers or activated components and the cask cavity to prevent movement during accident conditions of transport.

Explosives, non-radioactive pyrophorics, and corrosives (pH less than 2 or greater than 12.5), are prohibited. Pyrophoric radionuclides may be present only in residual amounts less than 1 weight percent. Materials that may auto-ignite or change phase (i.e., change from solid to liquid or gas) at temperatures less than 350°F, not including water, shall not be included in the contents. In addition, as required by 10 CFR 71.43 (d), the contents shall not include any materials that may cause any significant chemical, galvanic, or other reaction.

Powdered solids shipments shall be performed only when the most recent periodic leak test meets the requirements of Chapter 4, Section 4.8. Powdered solid radioactive material shall not include radioactive forms of combustible metal hydrides, combustible elemental metals, i.e., magnesium, titanium, sodium, potassium, lithium, zirconium, hafnium, calcium, zinc, plutonium, uranium, and thorium, or combustible non-metals, i.e., phosphorus.

For any package containing water and/or organic substances which could radiolytically generate combustible gases, a determination must be made that, over a period of time that is twice the expected shipping time, the hydrogen generated must be limited to a molar quantity that would be no more than 5% by volume (or equivalent limits for other inflammable gases) of the secondary container gas void if present at STP (i.e., no more than 0.063 g-moles/ft^3 at 14.7 psia and 70°F).
The determination of hydrogen generation will be made using the methods in NUREG/CR-6673, *Hydrogen Generation in TRU Waste Transportation Packages*. NUREG/CR-6673 has equations that allow prediction of the hydrogen concentration as a function of time for simple nested enclosures and for packages containing multiple contents packaged within multiple nested confinement layers. The inputs to these equations include the bounding effective $G(H_2)$-value for the contents, the $G(H_2)$-values for the packaging material(s), the void volume in the containment vessel and in the confinement layers (when applicable), the temperature when the package was sealed, the temperature of the package during transport, and the contents decay heat.

For any package delivered to a carrier for transport, the secondary container must be prepared for shipment in the same manner in which the determination for gas generation is made. Shipment period begins when the package is prepared (sealed) and must be completed within twice the expected shipping time.

For any package containing materials with radioactivity concentration not exceeding that for LSA and shipped within 10 days of preparation, or within 10 days of venting the secondary container, the gas generation determination above need not be made and the shipping time restriction does not apply.

1.2.3 Special Requirements For Plutonium

Any contents that contain more than 0.74 TBq (20 Ci) of plutonium must be in solid form.

1.2.4 Operational Features

Refer to the General Arrangement Drawing of the package in Appendix 1.3. There are no complex operational requirements associated with the package

1.3 APPENDIX

CNS 8-120B Shipping Cask Drawing

Withheld from public disclosure as security-related sensitive information

5.0 SHIELDING EVALUATION

5.1 Description of Shielding Design

The Model 8-120B packaging consists of a lead and steel containment vessel which provides the necessary shielding for the various radioactive materials to be shipped within the package. (Refer to Section 1.2.3 for packaging contents.) Tests and analysis performed under chapters 2.0 and 3.0 have demonstrated the ability of the containment vessel to maintain its shielding integrity under normal conditions of transport. Prior to each shipment, radiation readings will be taken based on individual loadings to assure compliance with applicable regulations as determined in 10CFR71.47 (see Section 7.1, step 13c).

The 8-120B will be operated under "exclusive use" such that the contents in the cask will not create a dose rate exceeding 200 mrem/hr on the cask surface, or 10 mrem/hr at two meters from the outer lateral surfaces of the vehicle. The package shielding must be sufficient to satisfy the dose rate limit of 10CFR71.51(a) (2) which states that any shielding loss resulting from the hypothetical accident will not increase the external dose rate to more than 1000 mrem/hr at one meter from the external surface of the cask.

5.1.1 Shielding Design Features

The cask side wall consists of an outer 1.5 inch thick steel shell surrounding 3.35 inches of lead and an inner containment shell wall of 0.75 inch thick steel. Total material shield thickness is 2.25 inches of steel and 3.35 inches of lead.

The primary cask lid consists of two layers of 3.25 inch thick steel, giving a total material shield thickness of 6.5 inches of steel. This lid closure is made in a stepped configuration to eliminate radiation streaming at the lid/cask body interface.

A secondary lid is located at the center of the main lid, covering a 29.0 inch opening. The secondary lid is constructed of two 3.25 inch steel plates with multiple steps machined in the secondary lid. These match steps in the primary lid, eliminating radiation streaming pathways. A stainless steel thermal shield covers the secondary lid and is attached to the secondary lid lifting lugs. The thermal shield is conservatively ignored in the shielding evaluation.

5.1.2 Maximum Radiation Levels

The 8-120B package carries a range of contents, from small concentrated sources to large volume homogeneous materials and combinations of these, and may include nearly every radionuclide. In order to determine the maximum activity of any particular radionuclide or mixture of radionuclides, a series of evaluations of bounding source configurations over a range of gamma energies are performed. The resulting set of source limits ensure that any content meeting the source limit for the appropriate configuration and gamma energy will comply with the the most restrictive of the dose rate limits from 10 CFR 71.47 and §71.51. These evaluations are presented in Section 5.4.

In order to provide a concise summary of the results, the point source results for only Co-60 and Cs-137 are provided in Table 5.1. This table gives both normal

and accident condition dose rates for the maximum Co-60 and Cs-137 point source in the cask.

Table 5.1 - Summary of Maximum Dose Rates (mrem/hr)

	Package Surface		1 m from Surface		2m from 8' trailer
Condition	Side	Top/Bottom	Side	Top/Bottom	Side
NCT					
Co-60 Source	190.0	62.0	NA	NA	2.3
Cs-137 Source	117.5	190.0	NA	NA	3.8
Allowable	200	200	NA	NA	10.0
HAC					
Co-60 Source	NA	NA	82.5	29.5	NA
Cs-137 Source	NA	NA	424.5	85.8	NA
Allowable	NA	NA	1000.0	1000.0	NA

The following assumptions were used to develop the values given in the table.

5.1.2.1 **Normal Conditions**

The source is modeled as a point source (1 cm dia x 1 cm high) at the location within the cask cavity that yields maximum peak cask exterior dose rates (i.e., at the top corner of the cavity, or on the side of the cask cavity at an elevation between the top and bottom impact limiters). Reference 5.7.2 includes a complete summary of the package response functions for all source configurations of interest.

5.1.2.2 **Accident Conditions**

(1) Lead slump of 0.15" resulting from the accident drop analysis is incorporated in the model

(2) Thinning of the lead shield layer due to the puncture drop is incorporated by reducing the lead thickness by 0.5"

(3) The source is modeled as a point source (1 cm dia x 1 cm high) in the top corner of the cavity (partially up into the chamfer region at the bottom corner of the primary cask lid). Reference 5.7.2 includes a complete summary of the package response functions for all source configurations of interest.

5.1.2.3 **Conclusion**

For the Co-60 point source case, the maximum allowable payload gamma source is governed by the 200 mrem/hr dose rate limit that applies on the cask body side, under NCT. The results determine a maximum allowable source strength of 1.073×10^{11} γ/sec (1.45 Ci) for that isotope. At this source strength, the results show a dose rate of close to 200 mrem/hr on the package side surface, and dose rates that are well under their regulatory limits at all other locations. An administrative margin of 5% is then applied (to account for any uncertainties), which reduces the allowable Co-60 gamma source strength to 1.019×10^{11} γ/sec

(1.38 Ci). Because of the 5% administrative margin, the actual peak dose rate is 190.0 mrem/hr, as shown in Table 5.

For the Cs-137 point source case, the maximum allowable payload gamma source strength is governed by the 200 mrem/hr dose rate limit that applies on the package top surface, under NCT. The results determine a maximum allowable source strength of 2.305 x 10^{12} γ/sec (73 Ci) for that isotope. At this source strength, the results show a dose rate of close to 200 mrem/hr on the package surface, and dose rates that are well under their regulatory limits at all other locations. An administrative margin of 5% is then applied (to account for any uncertainties), which reduces the allowable Cs-137 gamma source strength to 2.19 x 10^{12} γ/sec (69.6 Ci). Because of the 5% administrative margin, the actual peak dose rate is 190.0 mrem/hr, as shown in Table 5.1.

As the results do not exceed the allowable dose rates, the 8-120B cask meets the shielding requirements of 10 CFR Part 71.

5.2 Source Specification

5.2.1 Gamma Source

Analyses are performed for idealized source configurations that bound any actual source configuration that may occur. These bounding configurations are: a point source at the center of the cask cavity in the NCT configuration, a point source at the side of the cask cavity in the NCT configuration, a point source at the top corner of the cask cavity in the NCT configuration, a point source in the top corner of the cask cavity in the HAC configuration, and a uniform mass of material within a defined source region, as described in Section 5.4, for both NCT and HAC configurations. Further details of the analyses are found in Ref. 5.7.2.

All of the analyses described above are performed for several gamma energy levels, ranging from 0.5 MeV to 3.5 MeV. Two specific isotope cases, Co-60 and Cs-137 (and the corresponding specific gamma energies) are also analyzed. The Cs-137 source includes an equilibrium amount of Ba-137m. The gamma energy and abundance of Co-60 and Cs-137 are shown in Table 5.2.

Table 5.2 – Gamma Energy and Abundance

Radionuclide	Gamma Energy MeV	Abundance # of Gamma/decay
^{60}Co	1.176	1
	1.333	1
^{137}Cs	0.662	0.85

5.2.2 Neutron Source

There are no significant sources of neutron radiation in the radioactive materials carried in the 8-120B cask that result in measureable neutron doses outside the cask. A shielding analysis (SAR Chapter 5) for a cask with a similar geometry

and shield materials (Ref. 5.7.4) shows that a 1.1 E+08 n/s neutron source produces a dose rate of 9.4 mrem/hr at 2m from the side of the trailer. Limiting the neutron emission rate from the 8-120B contents to less than 1 E+05 n/s will result in a dose rate less than 0.1 mrem/hr. Thus, setting the total neutron emission to less than 1 E+05 n/s will result in a neutron dose rate that is a small fraction of the transport limit.

5.2.3 **Beta Source**

Significant beta emitters may be qualified as equivalent gammas as described in Section 5.4.4.

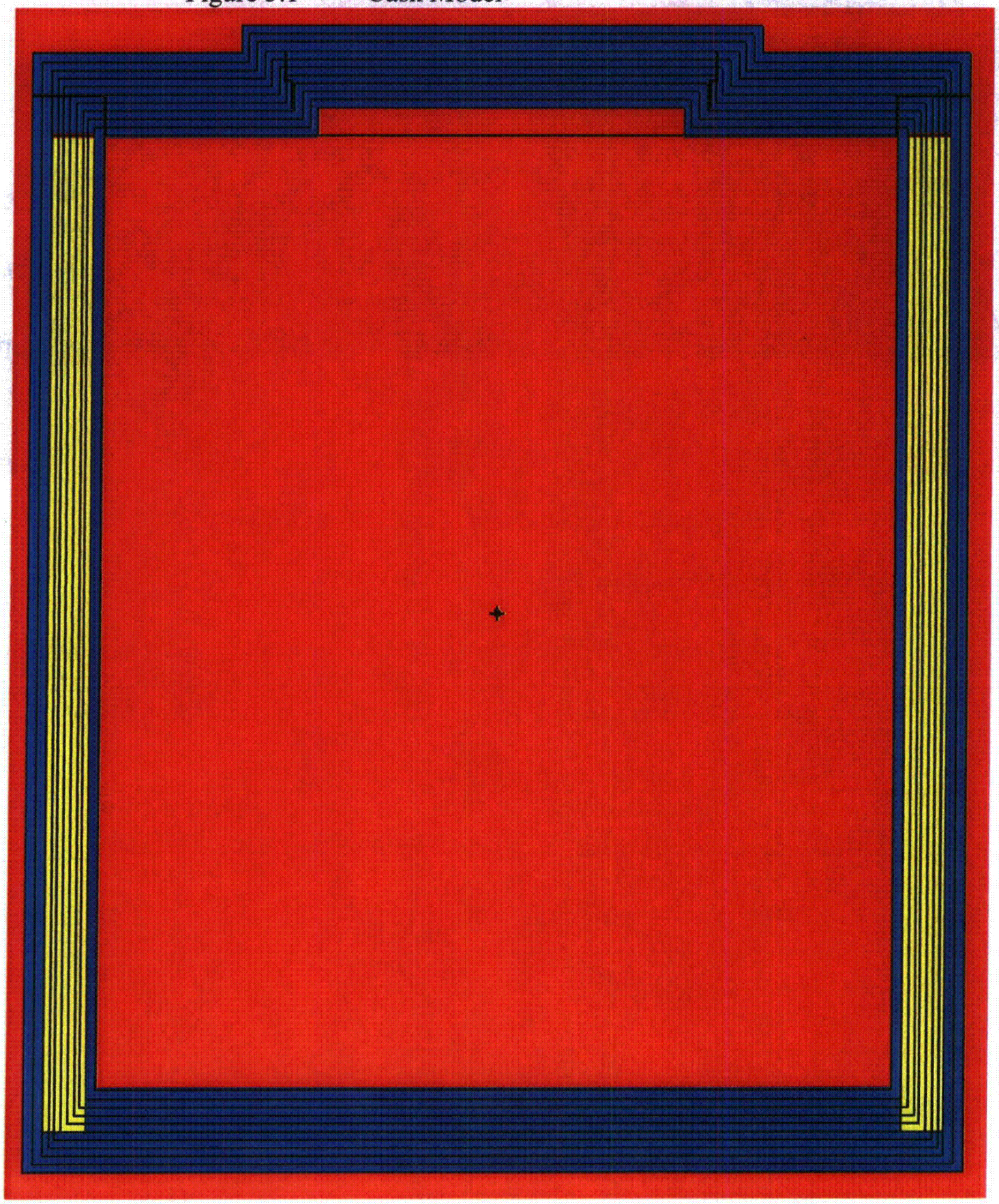
5.3 Model Specification

5.3.1 Description of Radial and Axial Shielding Configuration

Normal Conditions of Transport (NCT)

The walls of the 8-120B cask, 0.75" inner and 1.5" outer steel walls, with a 3.35" lead layer between, are modeled as cylindrical shells around the cavity cylinder. The base and lid of the cask are two 3.25" steel plates, for a total thickness of 6.5". This geometry is shown in Figure 5.1; the impact limiters are not shown. The cask is transported upright, i.e., with the axis of the cylinder vertical. Doses are evaluated at contact with the cask sidewall, the impact limiter surface, and at 2m from the 8' wide trailer.

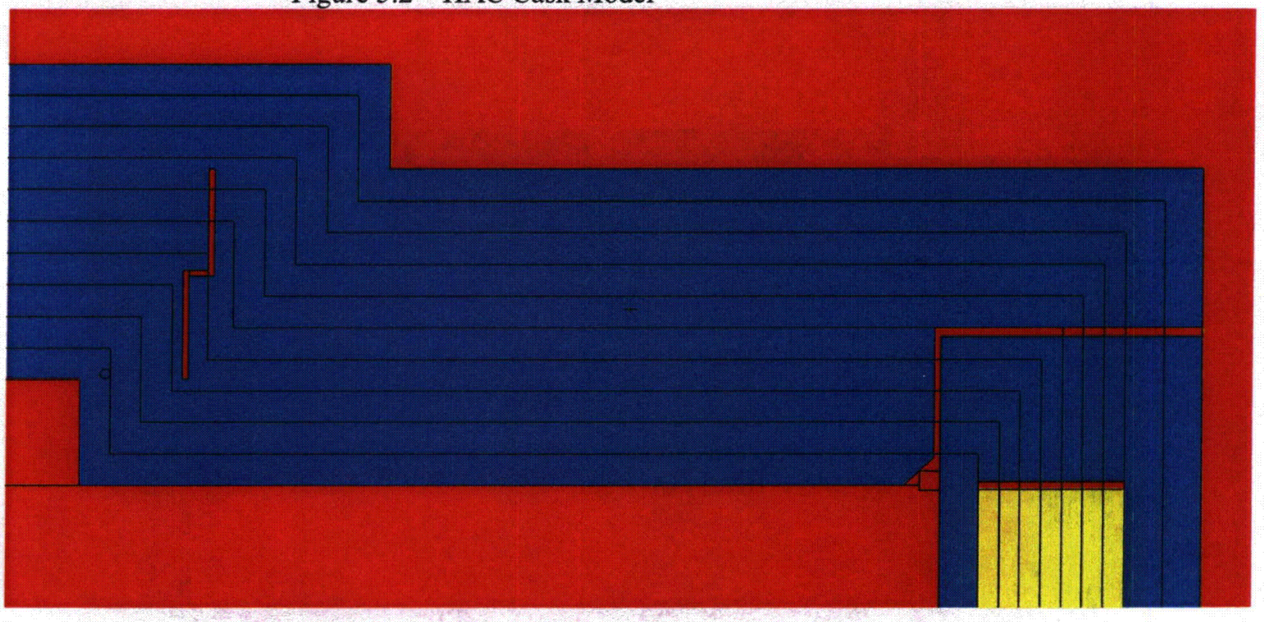
Figure 5.1 Cask Model



Hypothetical Accident Conditions (HAC)

As discussed in Chapter 2, the hypothetical accident 30' drop results in a 0.15" lead slump and the puncture drop causes a local ½" thinning of the lead layer. The HAC model has a 0.15" air-filled void at the top of the lead shield layer. Also, to conservatively reflect the puncture drop thinning, the thickness of the radial lead shield is reduced by ½" in the HAC model. The impact limiters are conservatively ignored. The HAC model is shown in Figure 5.2. Doses are determined at 1 m from the sidewall and the lid.

Figure 5.2 – HAC Cask Model



See Reference 5.7.2 for additional details of the MCNP models.

5.3.2 **Material Properties**

The compositions and densities of the materials modeled in the shielding analyses are described in Table 5.3 below. The table also lists the MCNP material/cross-section identifier (ZAID) for each modeled material.

Table 5.3 – Material Composition and Density

Material	Total Density (g/cc)	Composition	MCNP ZAID
Carbon Steel	7.82	99% Fe 1% C	26000.84p 8000.84p
Lead	11.34	100% Pb	82000.84p
Air	0.001205	76.508% N 23.479% O 0.013% C	7000.84p 8000.84p 6000.84p

5.4 **Shielding Evaluation**

The 8-120B package carries a range of contents, from small concentrated sources to large volume homogeneous materials and combinations of these, and may include nearly every

radionuclide. In order to determine the maximum source strength of any particular radionuclide or mixture of radionuclides, a series of evaluations of bounding source configurations over a range of gamma energies are performed to determine the maximum source strength (γ/sec) or maximum source strength density (γ/sec·g) for each combination of configuration and energy that results in the meeting the most restrictive of the dose rate limits from 10 CFR 71.47 and §71.51. The resulting set of source strength limits ensure that any content meeting the source strength limit for the appropriate configuration and gamma energy will comply with the §71.47 and §71.51 limits.

5.4.1 Methods

The gamma dose rates were calculated using MCNP Version 5, rev. 1.51.

In addition to the point source locations noted in Section 5.2, a uniformly-distributed gamma source is modeled within the source region. The uniform mass that fills the defined source region is zirconium, iron, or aluminum, whichever has the more conservative (smaller) attenuation coefficient at the gamma energy thus bounding other contents materials. The uniform mass is set at a density of 9.0 g/cc, which exceeds the density of nearly all expected payloads. Since the distributed source analyses determine limits in source strength density (γ/sec·g), this density bounds all other lower density contents. Defined source regions include the entire cask interior cavity, a "55 gallon" source zone centered within the cavity and a 2.5 ft^3 source zone centered within the cavity. All the above source zones are modeled for the NCT cask configuration. For the HAC cask configuration, only the full-cask-cavity source zone is modeled.

For the normal condition of transport (NCT) cases, dose rates are tallied on the vertical surface two meters from the package/transporter side (i.e., 322 cm from the cask centerline), and on the package surface which includes the impact limiter side and end surfaces as well as the cask body side cylindrical surface that lies between the impact limiters.

For the HAC point source cases, the dose rates are tallied at two locations on the surface one meter from the cask body. One location lies on the radial one meter surface, directly across from the source point (viewing the source point through the lead slump gap). The second location lies on the top one meter surface, directly above the source point, viewing the source point through the gap between the radial cask body and the lower part of the primary cask lid.

For the HAC distributed source cases, the dose rates are tallied over the entire spans of the surfaces that lie one meter from the side, top and bottom of the cask body.

For each of the analyses, the peak dose rates (per source gamma) that occur on each of the (NCT or HAC) regulatory surfaces described above are determined.

From these peak dose rates, limits are calculated over the range of gamma energies 0.5-3.5 MeV and for the radionuclides Co-60 and Cs-137. The limits are determined, in source strength (γ/sec) for the point source configurations and in source strength density (γ/sec·g) for the distributed source cases. The regulatory dose rate limit for each surface is divided by the highest per-source-gamma dose rate for that surface, to yield a maximum source strength, in γ/sec. The lowest of the allowable source strengths is then selected as the limiting gamma source strength for that case. Then, for the distributed source cases (only), the allowable source strength is divided by the modeled source region mass to yield the allowable source strength density in γ/sec·g.

Analysis Method Uncertainties and Conservatisms

The MCNP-calculated dose rates are adjusted upwards to account for statistical uncertainty in the MCNP results before they are used to determine source limits. These statistical uncertainties (which are conservatively accounted for in the source limit calculations) are less than 5% for all MCNP results that govern payload source limits.

Uncertainties in the analyses performed to demonstrate that an upper-bound payload material density (of 9.0 g/cc) yields maximum cask exterior dose rates may result in an uncertainty of less than 1% in the final dose rate results. Uncertainties in evaluations performed to determine the most conservative payload material (element) to be modeled in the 0.5 MeV and 3.5 MeV gamma analyses may also result in an uncertainty of ~1% in the final dose rate results. Finally, cask exterior dose rate contributions from neglected beta sources (discussed below in Section 5.4.4) could increase the final dose rate results by as much as ~1%.

The above analytical uncertainties, which could yield as much as a 3% increase in cask exterior dose rates, will be more than offset by conservatisms in the analysis method, for virtually all actual payloads. Conservatisms include neglecting all payload self shielding and concentrating the source into a point, in the worst possible cavity location, in the γ/sec limit calculations, modeling the entire cask cavity as being filled with the highest source strength density material (that occurs anywhere within the payload) in the γ/sec·g limit calculations, rounding gamma energies up (to the nearest evaluated value) when determining source strength limits, and modeling the lowest attenuation material within the payload to determine the γ/sec·g limit. Also, as discussed below in Section 5.4.4, the method used to treat beta sources is conservative by more than a factor of 100.

The sources of uncertainty and conservatism in the analyses are discussed in more detail in Reference 5.7.2.

Although the conservatisms in the analysis would more than offset any uncertainties, for virtually all actual payloads, all final payload source limits are reduced by an administrative margin of 5%, to account for uncertainties in the analysis.

5.4.2 Input and Output Data

The MCNP input and output files are found in Reference 5.7.3. The input file lists the inputs that define the source dimensions, shield dimensions, materials and density, and source spectrum.

5.4.3 Flux-to-Dose-Rate Conversion

The flux to exposure rate conversion factors are listed in Table 5.4 (Ref. 5.7.1).

Table 5.4 - Gamma-Ray-Flux-To-Dose-Rate Conversion Factors (ANSI/ANS-6.1.1 1977)

Gamma Energy (MeV)	DCV (rem/hr) per (γ/cm^2-sec)
0.015	1.95E-06
0.025	8.01E-07
0.045	3.17E-07
0.08	2.61E-07
0.15	3.79E-07
0.30	7.59E-07
0.50	1.15E-06
0.65	1.44E-06
0.75	1.60E-06
0.90	1.83E-06
1.25	2.32E-06
1.75	2.93E-06
2.5	3.72E-06
3.5	4.63E-06
4.5	5.42E-06
5.5	6.19E-06
6.5	6.93E-06
7.5	7.66E-06
9.0	8.77E-06
12.0	1.10E-05

5.4.4 External Radiation Levels and Source Strength Limits

Gamma Source Strength Limits

The results of the analyses of the bounding configurations are compared to the external radiation limits allowed for the various compliance locations identified in §71.47 and §71.51. The configuration, at each energy, that has the largest ratio of result to limit is set as the governing configuration from which the limits are established.

The final results of the shielding evaluation are the limits on payload gamma source strength (γ/sec) and payload gamma source strength density (γ/sec·g), which vary as a function of gamma energy and payload configuration. These limits are presented, for all gamma energies and all analyzed source configurations, in Table 5.5 below. The limits are presented graphically in Figure 5.3 and Figure 5.4.

Table 5.5 - Final Payload Source Strength and Source Strength Density Limits

Energy (MeV)	General Sources		Discrete Sources (shored at centroid)*		
	Source γ/sec	Source Density γ/sec·g	Source γ/sec	Source Density γ/sec·g	
				2.5 ft^3	55 gal
	❶	❷	❸	❹	❺
3.50	7.903E+09	3.502E+05	2.227E+11	2.378E+06	1.260E+06
2.75	1.045E+10	5.471E+05	3.001E+11	3.696E+06	1.961E+06
2.25	1.477E+10	8.879E+05	4.136E+11	5.789E+06	3.085E+06
1.83	2.426E+10	1.701E+06	5.774E+11	1.071E+07	5.745E+06
1.50	4.776E+10	3.988E+06	8.307E+11	2.410E+07	1.301E+07
1.17	1.641E+11	1.092E+07	1.426E+12	7.866E+07	5.217E+07
0.90	8.629E+11	3.447E+07	2.513E+12	2.538E+08	1.578E+08
0.70	1.815E+12	1.164E+08	4.407E+12	8.365E+08	4.999E+08
0.50	6.237E+12	7.702E+08	1.058E+13	5.318E+09	3.103E+09
Co-60	1.073E+11	7.997E+06	1.236E+12	5.713E+07	3.303E+07
Cs-137	2.305E+12	1.556E+08	5.158E+12	1.145E+09	6.549E+08

**For discrete source limits, use columns ❸ and ❹ when the payload object meets the 2.5 ft^3 size criteria, or columns ❸ and ❺ when it meets the 55 gallon size criteria. When the size meets neither criteria use columns ❶ and ❷.*

The "general" source limits shown in the left side of Table 5.5 apply for payloads that fill most of the cask cavity or are not shored within a smaller volume at the cavity center. The discrete source limits shown in the right part of Table 5.5 may apply if the payload meets the size criteria and is shored to the center of the cask cavity. (There are also restrictions on height and diameter, for payloads qualified under the "2.5 ft^3" and "55 gal" limits shown above in Table 5.5, which are discussed in Chapter 7 of this SAR.)

Detail of the calculations (and process) used to determine the payload source limits shown in Table 5.5 are found in Ref. 5.7.2. Note a 5% administrative margin is applied which effectively reduces all the source strength limits presented above in Table 5.5 by 5%. Application of the margin (as part of the sum of fractions method) is discussed below in Section 5.5.

Figure 5.3 - Payload Gamma Source Strength Limit vs. Gamma Energy

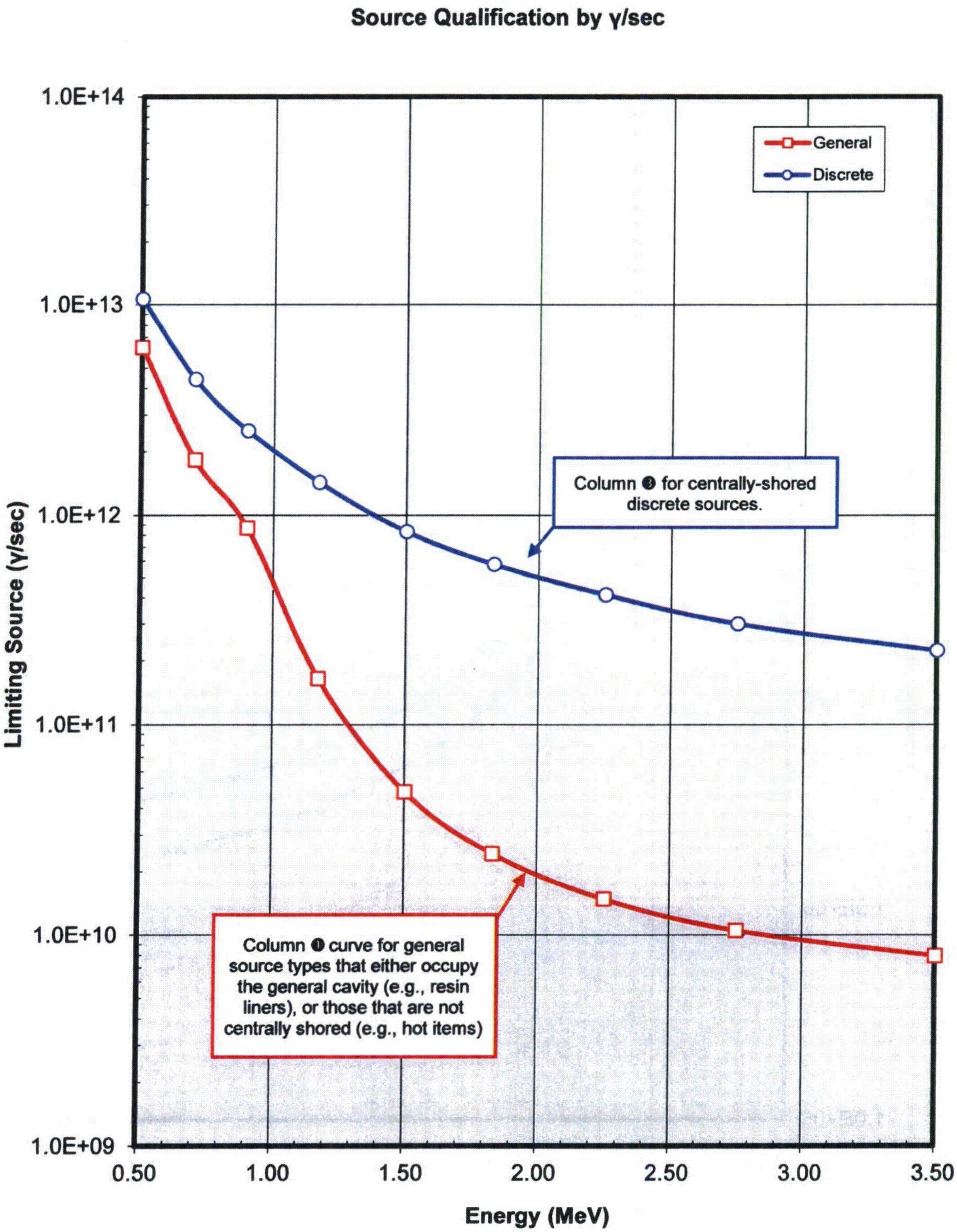
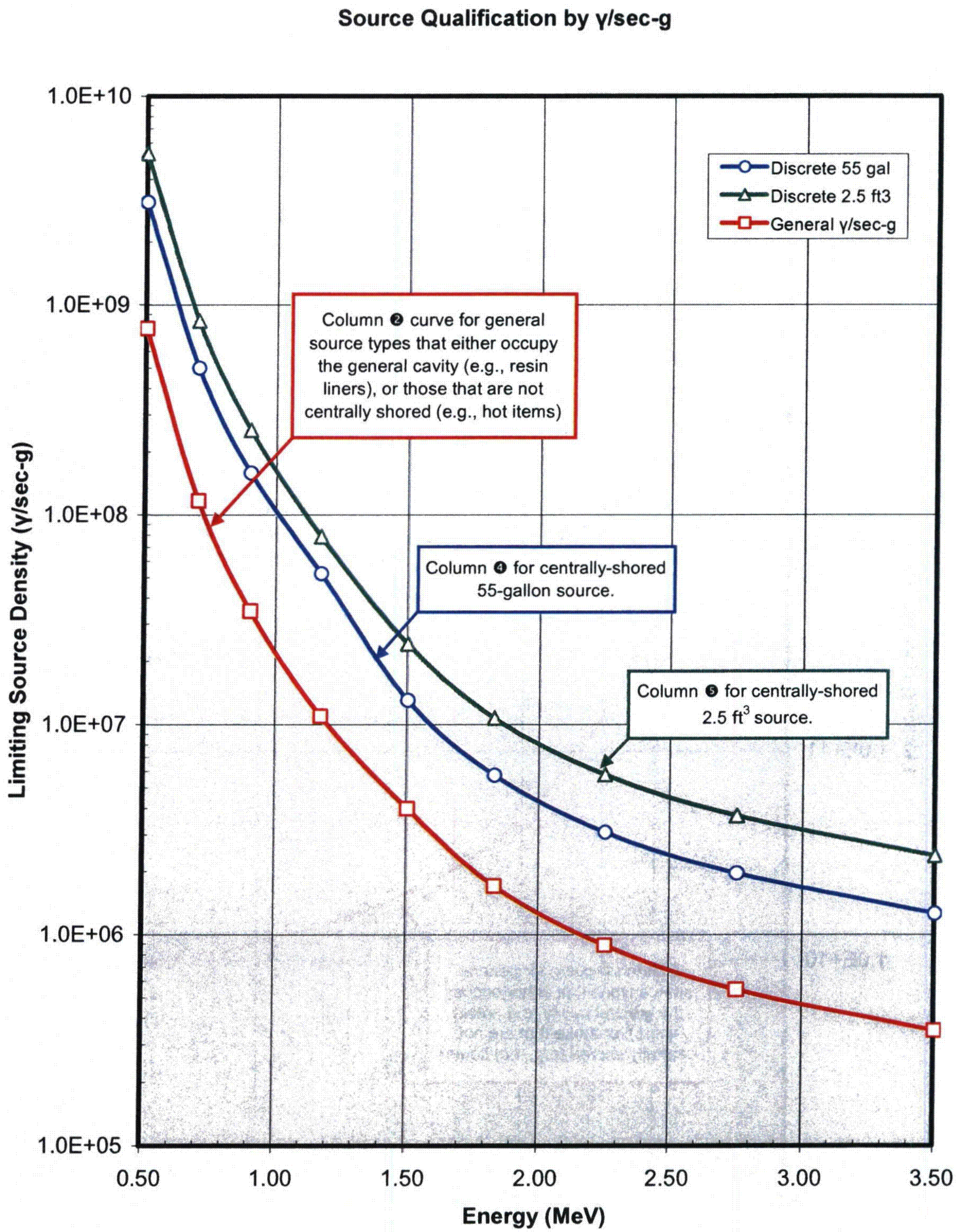


Figure 5.4 - Payload Gamma Source Strength Density Limit vs. Gamma Energy



Beta Source Strength Limits

Beta particles lose their energy continuously as they pass through matter, emitting Bremsstrahlung gammas over their range. These Bremsstrahlung gammas, however, have the potential to be significant contributors to package dose rates because the allowable (3000 A_2) source activity for betas can be much higher than for gamma emitters (e.g., as much as 42,000 Ci of ^{32}P vs. 4144 Ci of ^{137}Cs). The method for qualifying significant 8-120B beta emitters is to represent the beta emitter as an equivalent gamma emitter and treat it like any other gamma energy line per the methods described in Section 5.5.

This method is only applied to beta sources (pure beta emitters) with activities greater than 2E+12 betas per second, and peak beta energy levels between 0.3 MeV and 3.5 MeV. Isotopes with peak beta energies less than 0.3 MeV can be neglected. Isotopes with peak beta energies over 3.5 MeV may not be shipped in the cask. Beta source strengths less than 2E+12 betas per second do not contribute significantly to cask exterior dose rates and are, thus, not significant. See Ref. 5.7.2 for additional details and validating calculations.

The beta source can be converted to an equivalent gamma source by:

$$S_\gamma = S_\beta \cdot \frac{S_\gamma}{S_\beta} \text{ where}$$

S_γ = equivalent monoenergetic gamma source strength, γ/sec, at the maximum beta energy E_{max}.
S_β = beta source strength, β/sec, at the beta energy spectrum for the nuclide of interest and

$$\frac{S_\gamma}{S_\beta} = (\textit{fraction of energy converted from betas to photons})\left(\frac{\textit{beta } E_{avg}}{\textit{photon energy}}\right)$$

Conservatively assume all gammas are at the beta maximum energy E_{max}, the energy ratio becomes:

$$\frac{S_\gamma}{S_\beta} = f\left(\frac{E_{avg}}{E_{\max}}\right)$$

where
E_{avg} = average energy of the beta source distribution, MeV
E_{max} = maximum energy of the source distribution, MeV.

The fraction of the incident beta energy that is converted to gamma energy, f, is given by (Ref. 5.7.3)

$$f \cong 3.5 \times 10^{-4} ZE_{\max}$$

where
f = the fraction of the incident beta energy that is converted to gamma energy,
Z = atomic number of the absorber

So

$$\frac{S_\gamma}{S_\beta} = 3.5 \times 10^{-4} ZE_{\max}\left(\frac{E_{avg}}{E_{\max}}\right)$$

The resulting equation to convert a beta source to an equivalent gamma source at the beta's maximum energy is therefore:

$$S_\gamma = S_\beta\left(3.5 \times 10^{-4} ZE_{avg}\right)$$

For a single material absorber, use the Z of the material. For compounds or mixtures, use a weighted average Z_w:

$$Z_W = \sum_{i=1}^{n}\left(\frac{m_i}{m_{total}} \cdot Z_i\right)$$

Z_w should be determined, as described above, for both the waste payload and the wall of the secondary container (liner) that the waste resides in. Then, the higher of the two Z_w values should be conservatively used as the basis of the equivalent gamma source calculation. This conservatism is necessary since it is not known what fraction of the beta-to-gamma conversion occurs within the waste material and within the secondary container wall material.

The proposed method for qualifying significant 8-120B beta emitters is to represent the beta emitter as an equivalent gamma emitter and treat it like any other gamma energy line per the methods described in the remainder of this calculation. In this way, significant beta emitters can be accounted for along with other gamma emitters. The entire (equivalent) gamma source (S_γ) is modeled at the same energy as the peak beta energy for the beta-emitting isotope. This gamma energy level is rounded up to the nearest (higher) gamma energy level for which source limits are presented in Table 5.5.

For common container and waste materials (for which Z is 26 or less), the formula above yields an equivalent gamma source that is less than 1% of the isotope's beta source. Furthermore, comparisons to rigorous MCNP beta shielding analyses show that the method (and formula) described above yields cask exterior gamma dose rates (due to payload beta emissions) that are conservative (high) by more than a factor of 100. Thus, a beta source will yield cask exterior dose rates that are only ~0.01% as high as the cask exterior dose rates produced by a gamma source of the same strength and energy level.

For the above reasons, the beta source for isotopes that emit both betas and gammas can be neglected, since any cask exterior dose rate contributions from the beta source will be negligible compared to those produced by the isotope's gamma source. Thus, the procedure described above is only to be used for pure beta-emitting isotopes with a significant beta source.

A procedure for evaluating beta emitters is included in Chapter 7 Attachment 1 which establishes limits for large activity beta sources.

5.5 Payload Qualification

Radioactive 8-120B contents must be qualified to ensure the shipment will meet the regulatory dose limits from §71.47 and §71.51

To qualify a payload, the cask user determines 1) a gamma source strength (γ/sec) and 2) a gamma source strength density (γ/sec·g) for their payload, based on the gamma energy that applies for the payload, whether the payload is shored at the cavity centroid, and the size and volume of the payload. The payload qualifies for shipment in the 8-120B cask if it meets either one of the source strength or source strength density limits in Table 5.5. Note that when determining compliance with the source strength density limit, the highest source strength density (or "hottest") section of the waste must be used (i.e., the "hottest" material that occurs anywhere within the waste or within any waste/payload item). Averaging of the source strength density, between payload items or within any payload item, is not allowed.

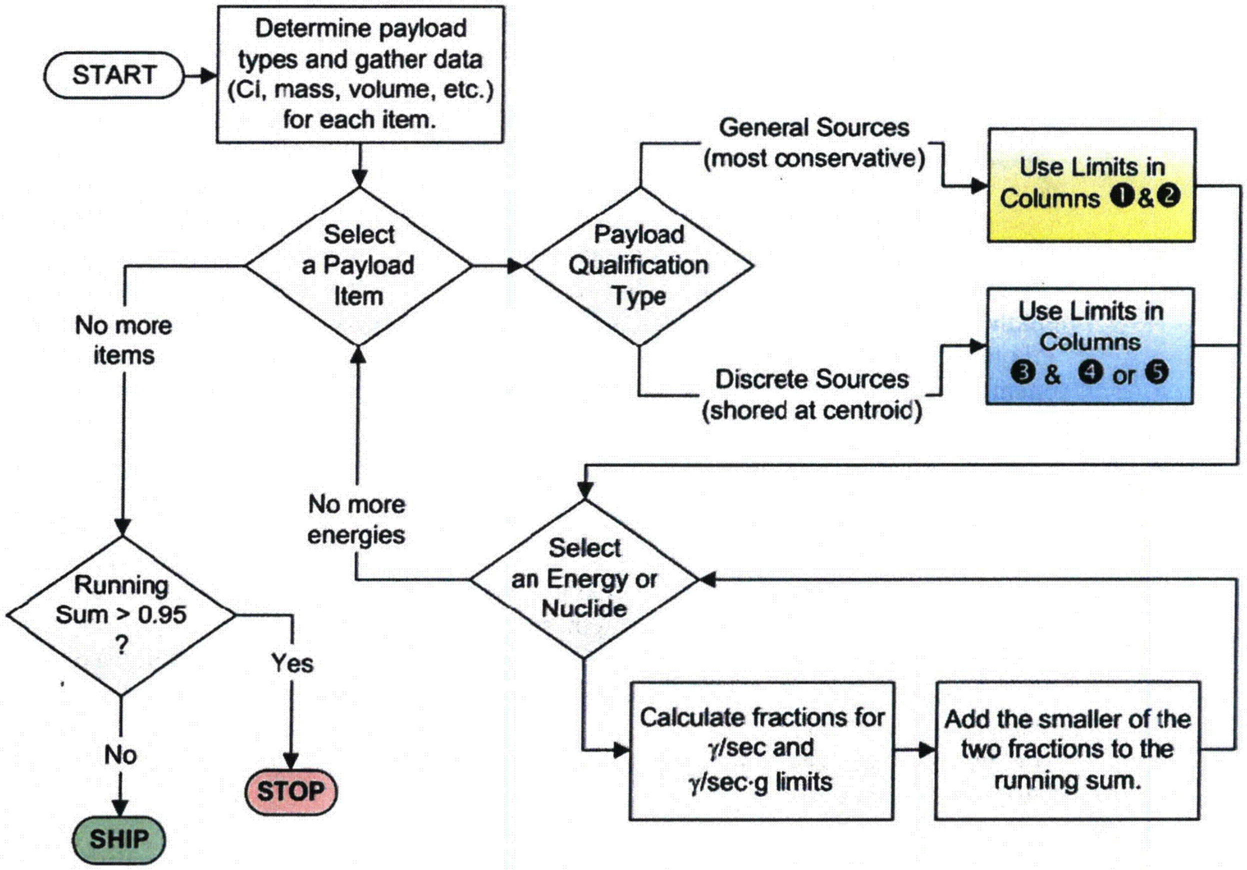
To qualify payloads that emit gammas at multiple energies or when portions of the payloads are radiologically different, a sum of fractions approach is used. For multiple payload items, the user performs a separate qualification evaluation for each payload item/energy, and then use a sum of fractions approach to qualify the overall cask payload. For each gamma energy or payload item, two fractions are determined, one based on the ratio of the payload source strength (γ/sec) over the allowable source strength, and one based on the ratio of the source strength density (γ/sec·g) over the allowable source strength density. The lower of the two fractions is then selected, for each gamma energy or payload item. The resulting fractions are then summed. The total (sum of fractions) may not exceed 0.95.

Note that the qualification procedure is performed for each gamma energy emitted by the waste, and that the procedures performed for each gamma energy are completely independent. Thus, a payload item may qualify under the γ/sec limit for one gamma energy, and qualify under the γ/sec·g limit for a different gamma energy (although this is unlikely). Each gamma energy is evaluated separately because a separate, independent shielding analysis is performed for each gamma energy. For each gamma energy, the γ/sec and γ/sec·g limits are determined using shielding models that are bounding for any payload configuration. Thus, for each gamma energy, any payload that meets <u>either</u> the γ/sec limit or the γ/sec·g limit (established for that gamma energy) will not yield cask exterior dose rates over regulatory limits. Cask exterior dose rate contributions from multiple gamma energies are effectively summed through the use of the sum of fractions approach described above.

When determining the γ/sec and γ/sec·g limits, payload gamma energy levels are conservatively rounded up to the nearest (higher) gamma energy level for which source limits are presented in Table 5.5. Given this rounding, multiple payload gamma energies can be combined into a single, overall source, which is then compared to the source strength limits (shown in Table 5.5) which correspond to a gamma energy that is equal to or higher than that of all the gamma energies within the combined group.

This qualification process is shown in the flowchart below (Figure 5.5)

Figure 5.5 - Payload Qualification Flow Chart



5.6 Conclusion

The cask shielding must be able to limit the dose rate to the limits of §71.47 and §71.51. This section demonstrates compliance with this requirement. Structural analysis (Section 2.0) demonstrates that the cask wall will not fail during the hypothetical accident. However, lead slump may occur during a drop giving an isolated region in the sidewall without lead. Lead slump cannot occur in the lid or bottom of the cask since lead is not present in these parts of the cask. With application of the source qualification process from Section 5.5, the contents will meet the dose rate limits.

5.7 References

5.7.1 ANSI/ANS 6.1.1-1977, "Neutron and Gamma-Ray Flux-to-Dose-Rate Factors."
5.7.2 ES Calculation, NU-391 Rev. 3, "8-120B Shielding Response"
5.7.3 Cember, H., "Introduction to Health Physics," Pergamon Press, 2nd Ed.
5.7.4 ES Document, 10-160B SAR, Consolidated Revision. 5, 2012

7.0 OPERATING PROCEDURE

This chapter describes the general procedure for loading and unloading of the 8-120B Cask.

The maximum permissible activity is the lesser of the activity determined by:
1) Attachment 1 for beta and gamma emitters, 2) 3000 A_2, or 3) having a decay heat of 200 watts. Radioactive contents are to be transported as exclusive use, per 10 CFR 71.4.

For contents that could radiolytically generate combustible hydrogen, see Attachment 2 for instructions on determination of hydrogen concentration.

Powdered solids shipments require the package to be leaktight. The most recent periodic leak test must meet the requirements of Chapter 4, Section 4.9, Periodic Verification Leak Rate Determination for Leaktight Status.

7.1 Loading the Packaging

<u>Note:</u> Prior to loosening the impact limiter ratchet binders, inspect the exterior of the package for damage, e.g., large dents, gouges, tears to the impact limiter skin and thermal shield. Contact EnergySolutions if damage is present. The cask may not be used as a Type B package until the damage is assessed by Energy*Solutions* and repairs, if required, are made to achieve conformance with the drawings listed in the CoC.

7.1.1 Impact Limiter Removal

7.1.1.1 Loosen and disconnect ratchet binders from upper impact limiter.

7.1.1.2 Using suitable lifting equipment, remove upper impact limiter assembly. Care should be exercised to prevent damage to impact limiter during handling and storage.

7.1.2 Secondary Lid Thermal Shield Removal

7.1.2.1 Remove the ball lock pins from each of the three retaining pins and remove the retaining pins from secondary lid lift lugs.

7.1.2.2 Using suitable lifting equipment, remove the secondary lid thermal shield. Care should be taken to prevent damage to thermal shield during handling and storage.

7.1.3 Determine if cask must be removed from trailer for loading purposes. To remove cask from trailer:

7.1.3.1 Disconnect cask to trailer tie-down equipment.

7.1.3.1.1 Inspect cask lifting ear bolts for defects. Obtain replacement bolts as specified on the drawing listed in 5(a)(3) of the CoC for any bolts that show cracking or other visual signs of distress.

7.1.3.1.2 Inspect cask lifting ear threaded holes for defects. Contact Energy*Solutions* if any bolt holes show signs of cracking or visual signs of distress.

7.1.3.2 Attach cask lifting ears and torque bolts to 200 ft-lbs. ± 20 ft-lbs. lubricated.

NOTE: The cables used for lifting the cask must have a true angle, with respect to the horizontal of not less than 60°.

7.1.3.3 Using suitable lifting equipment, remove cask from trailer and the lower impact limiter and place cask in level loading position.

NOTE: In certain circumstances, loading may be accomplished through the secondary lid, into a pre-positioned waste liner that has been properly shored or into pre-positioned shoring, while the primary lid remains on the cask. Alternate "(A)" steps have been included to accommodate this situation.

7.1.4 Loosen and remove the twenty (20) bolts, which secure the primary lid to cask body.

7.1.4A Loosen and remove the twelve (12) bolts, which secure the secondary lid to the primary lid.

7.1.5 Inspect the bolts for defects. Obtain replacement bolts as specified on the drawing listed in 5(a)(3) of the CoC for any bolts that show cracking or other visual signs of distress.

NOTE: The cables used for lifting either lid must have a true angle, with respect to the horizontal, of not less than 45°.

7.1.6 Remove primary lid from cask body using suitable lifting equipment. Care should be taken during lid handling operations to prevent damage to cask or lid seal surfaces.

7.1.6A Remove secondary lid from cask body using suitable lifting equipment. Care should be taken during lid handling operations to prevent damage to cask or lid seal surfaces.

7.1.7 Inspect the bolts holes for defects. Contact Energy*Solutions* for any bolt holes that show signs of cracking or visual signs of distress.

7.1.8 Inspect cask interior for damage, loose materials or moisture. Clean and inspect seal surfaces. Replace seals when defects or damage is noted which may preclude proper sealing. Contact EnergySolutions if damage is present.

NOTE: Radioactively contaminated liquids may be pumped out or removed by use of an absorbent material. Removal of any material from inside the cask shall be performed under the supervision of qualified health physics personnel with the necessary H.P. monitoring and radiological health safety precautions and safeguards.

NOTE: When seals are replaced, leak testing is required as specified in section 8.2.2.1.

NOTE: Verify intended contents meet the requirements of the Certificate of Compliance.

NOTE: Ensure the contents, secondary container, and packaging are chemically compatible, i.e., will not react to produce flammable gases.

7.1.9 Place disposable liner, drums or other containers into the pre-positioned shoring and install additional shoring or bracing, if necessary, to restrict movement of contents during normal transport.

7.1.9A Process liner as necessary, and cap using standard capping devices. Provide shoring if necessary to limit movement during transport, or if required by the radiological qualification procedure of Attachment 1.

7.1.10 Clean and inspect lid seal surfaces.

7.1.11 Replace the primary lid on the cask body. Secure the lid by hand tightening the twenty (20) primary lid bolts.

7.1.11.1 Torque, using a star pattern, the twenty (20) primary lid bolts (lubricated) to 250 ft-lbs. ± 25 ft-lbs.

7.1.11.2 Re-Torque, using a star pattern, the twenty (20) primary lid bolts (lubricated) to 500 ft-lbs. ± 50 ft-lbs.

7.1.11A Replace the secondary lid on the primary lid. Secure the lid by hand tightening the twelve (12) secondary lid bolts.

7.1.11.1A Torque, using a star pattern, the twelve (12) secondary lid bolts (lubricated) to 250 ft-lbs. ± 25 ft-lbs.

7.1.11.2A Re-torque, using a star pattern, the twelve (12) secondary lid bolts (lubricated) to 500 ft-lbs. ± 5 0 ft-lbs.

7.1.12 Replace the vent port cap screw and seal (if removed) and torque to 20 ft-lbs. ± 2 ft-lbs.

NOTE: Leak test the primary lid and secondary lid O-rings and the vent port in accordance with Section 8.2.2.2, prior to shipment of the package loaded with greater than "Type A" quantities of radioactive material. For content exemptions of this test, refer to the current Certificate of Compliance No. 9168.

7.1.13 If cask has been removed from trailer, proceed as follows to return cask to trailer:

7.1.13.1 Using suitable lifting equipment, lift and position, cask into lower impact limiter on trailer in the same orientation as removed.

7.1.13.2 Unbolt and remove cask lifting ears.

7.1.13.3 Reconnect cask to trailer using tie-down equipment.

7.1.14 Installation of Upper Impact Limiter and Secondary Lid Thermal Shield

7.1.14.1 Using suitable lifting equipment, lift, inspect for damage and install the secondary lid thermal shield.

7.1.14.2 Install the three secondary lid thermal shield retaining pins into the secondary lid lift lugs and insert the ball lock pins into the retaining pins.

7.1.14.3 Using suitable lifting equipment, lift, inspect for damage and install upper impact limiter on cask in the same orientation as removed.

7.1.15 Attach and hand tighten ratchet binders between upper and lower impact limiter assemblies.

7.1.16 Cover lift lugs as required.

7.1.17 Inspect package for proper placards and labeling.

7.1.18 Complete required shipping documentation.

7.1.19 Prior to shipment of a loaded package, the following shall be confirmed:

7.1.19.1 That the licensee who expects to receive the package containing materials in excess of Type A quantities specified in 10 CFR 20.1906(a) meets and follows the requirements of 10 CFR 20.1906, as applicable.

7.1.19.2 That trailer placarding and package labeling meet DOT specifications (49 CFR 172).

7.1.19.3 That the provisions of 10 CFR 71.87 are met including that the external radiation dose rates are less than or equal to 200 millirem per hour (mrem/hr) at the surface and less than or equal to 10 mrem/hr at 2 meters in accordance with 10 CFR 71.47 by performing radiation surveys. These surveys should be sufficient to ensure that a non-uniform distribution of radioactivity does not cause the surface or 2m limit to be exceeded.
The SAR thermal analysis demonstrates that by meeting the 200w decay heat limit, the temperature requirement of 10 CFR 71.43(g) is met. No temperature survey is required.

7.1.19.4 That all security seals are properly installed.

7.1.19.5 Prior to shipping a loaded package, inspect the exterior of the cask for damage, e.g., large dents, gouges, tears to the impact limiter skin and thermal shield. Contact Energy*Solutions* if damage is present.

7.2 Unloading the Package

In addition to the following sequence of events for unloading a package, packages containing quantities of radioactive material in excess of Type A quantities specified in 10 CFR 20.1906(a) shall be received, monitored, and handled by the licensee receiving the package in accordance with the requirements of 10 CFR 20.1906, as applicable. Identification of packages containing greater than Type A quantities can be made by review of the shipping papers accompanying the shipment.

7.2.1 Move the unopened package to an appropriate level unloading area.

7.2.2 Perform an external examination of the unopened package. Record any significant observations.

7.2.3 Remove security seal(s), as required.

7.2.4 Impact Limiter Removal

7.2.4.1 Loosen and disconnect ratchet binders from upper impact limiter.

7.2.4.2 Using suitable lifting equipment, remove upper impact limiter assembly. Care should be exercised to prevent damage to impact limiter during handling and storage.

7.2.5 Secondary Lid Thermal Shield Removal

7.2.5.1 Remove the ball lock pins from each of the three retaining pins and remove the retaining pins from secondary lid lift lugs.

7.2.5.2 Using suitable lifting equipment, remove the secondary lid thermal shield. Care should be taken to prevent damage to thermal shield during handling and storage.

7.2.6 If cask must be removed from trailer, refer to Step 7.1.3.

7.2.7 Loosen and remove the twenty (20) primary lid bolts.

NOTE: The cables used for lifting the lid must have a true angle with respect to the horizontal of not less than 45 degrees.

7.2.8 Using suitable lifting equipment, lift lid from cask using care during handling operations to prevent damage to cask and lid seal surfaces.

7.2.9 Remove contents.

NOTE: Radioactively contaminated liquids may be pumped out or removed by use of an absorbent material. Removal of any material from inside the cask shall be performed under the supervision of qualified health physics personnel with the necessary H.P. monitoring and radiological health safety precautions and safeguards.

7.2.10 Assemble packaging in accordance with loading procedure (7.1.10 through 7.1.19).

7.3 Preparation of Empty Packaging for Transport

7.3.1 Confirm the cavity is empty of contents are far as practicable

7.3.2 Survey the interior; decontaminate the interior if the limits of 49 CFR 173.428(d) are exceeded

7.3.3 Install the lid.

7.3.3.1 Install the lid closure bolts.

7.3.3.2 Torque, using a star pattern, the twenty (20) primary lid bolts (lubricated) to 250 ft-lbs. ± 25 ft-lbs.

7.3.3.3 Re-Torque, using a star pattern, the twenty (20) primary lid bolts (lubricated) to 500 ft-lbs. ± 50 ft-lbs.

7.3.4 Re-install the vent port cap screw with the seal. Torque the vent port cap screw to 20±2 ft-lbs.

7.3.5 Decontaminate the exterior surfaces of the package as necessary.

7.3.6 Inspect the exterior and confirm it is unimpaired.

7.3.7 Using suitable lifting equipment, lift, inspect for damage and install the secondary lid thermal shield.

7.3.8 Install the three secondary lid thermal shield retaining pins into the secondary lid lift lugs and insert the ball lock pins into the retaining pins.

7.3.9 Using suitable lifting equipment, lift, inspect for damage and install upper impact limiter on cask in the same orientation as removed

7.3.10 Attach the tamper-indicating seals.

7.3.11 Confirm the requirements of 49 CFR 173.428 are met.

Attachment 1
Determination of Acceptable Beta and Gamma Source strength
(see Chapter 5 for the derivation of the beta and gamma source strength limits)

Background and Definitions

8-120B contents (payloads) have acceptable beta and gamma sources when they can be shown to meet the requirements in Table 1 using the procedure described in this Attachment. Source qualification is based on a sum-of-fractions method, where sources are broken down into separate gamma energy lines and compared to the corresponding limit for that group. For some payloads, it may be necessary to subdivide the payload into separate items, determining fractions for each item by energy group then summing the fractions to determine acceptability.

Table 1 categorizes the limits into source strength (γ/sec) and source strength density (γ/sec·g). For each energy, the fraction to be summed is the lowest of the γ/sec and γ/sec·g fractions. Table 1 has five columns of limits, denoted ❶ through ❺. Depending on the nature of the payload, the user must select a pair of columns to use for each payload item, one γ/sec column and one γ/sec·g column. The "general" payload columns (❶,❷) are the most conservative and are suitable for any payload item. Higher limits are acceptable for special cases where a reduced volume item is shored about the centroid of the package cavity (e.g., an isotope source). These are termed "discrete" payload items, and are distinguished as follows:

- Use the 2.5 ft^3 limits (❸,❹) when the payload item has a volume of 2.5 ft^3 (70,792 cm) or less, a height of 28 inches (71.16 cm) or less, and a diameter of 17.65 inches (44.84 cm) or less, and is shored at the centroid of the cavity.

- Use the 55-gallon limits (❸,❺) when the payload item has a volume of 7.7 ft^3 (218,868 cm^3) or less, a height of 33.5 inches (85.1 cm) or less, and a diameter of 25.7 inches (65.3 cm) or less, and is shored at the centroid of the cavity.

- If the payload item does not meet the requirements of either the 2.5 ft^3 or 55-gallon definitions, regardless of shoring, then use the γ/sec limit for general sources ❶, and the general γ/sec·g limit ❷.

Source limits from Table 1 may not be interpolated in energy. The proper procedure for gammas (and for equivalent bremsstrahlung gammas) is to round source energies up to the next higher energy level in Table 1.

For the purpose of qualification, the total γ/sec source strength for the entire payload is determined for each gamma energy group. Then, for each gamma energy group, the γ/sec·g source strength density is conservatively determined based on the highest source strength ("hottest") portion of the payload. Averaging of the source strength density is not allowed, either between payload items or within payload items. This conservative approach ensures that package dose rate limits will be met, even for payloads for which the source strength density is not uniform within its volume/mass, since the analysis and qualification is based on the highest source strength density material that occurs anywhere within the payload. Once the applicable

γ/sec source strength and γ/sec·g source strength density are determined for the payload, they are compared to the corresponding limits that are determined as discussed above.

For some payloads, use of the highest source strength density may be inappropriately conservative (e.g., payloads with a small mass of high source strength density material within a large mass of much lower source strength density material). The qualification methodology takes these payloads into consideration, and allows the payload to be separated into distinct components (or "payload items"), for which the qualification process is performed separately (e.g., one qualification for the high source strength density components/materials and another qualification for the low source strength density materials). As an example, for radiologically non-homogenous materials such as contaminated soil with hot "chunks", the components would be the soil and the hotter particles.

Crud/contamination (or any similar finely distributed powder or granular) sources must be treated separately if there is a potential for redistribution (i.e., if the source is not chemically or physically bound to its substrate or bulk material). In such cases, the crud (or powder) source component must be qualified using only the γ/sec limits.

Gamma sources below 0.3 MeV may be neglected. Any sources with gamma energies above 3.5 MeV are not qualified at this time. Table 1 has two special rows for the common radioactive nuclides, ^{60}Co and ^{137}Cs; and so their fractions may be calculated directly without breaking them down into their separate energy lines.

Pure beta emitters (e.g., ^{3}H, ^{32}P, ^{35}S, ^{90}Sr, ^{90}Y) can affect package exterior gamma dose rates due to bremsstrahlung radiation. These emitters must therefore be qualified by converting the beta source strength into an equivalent bremsstrahlung (gamma) source and entering the equivalent gammas like any other gamma source line in the sum-of-fractions. Beta sources with maximum beta energies below 0.3 MeV or payload source strengths less than 2E+12 β/sec may be neglected. Beta sources with peak beta energies over 3.5 MeV are not qualified at this time. Beta source strength from isotopes with significant gamma source strength may also be neglected. The method for converting betas is presented in the procedure below and the methodology is discussed in Chapter 5 of the SAR.

Payload items with densities between 0.0 and 9.0 g/cc are within the range of validity for Table 1 γ/sec·g limits. Most materials fall within this range, with the exception of lead and some exotic metals. Do not consider liner, or other secondary container, materials when calculating density. Densities are for the basic material, and should not include voids. Radioactive payload items with densities above 9.0 g/cc must be qualified using the γ/sec limits alone.

In summary, all sources must be accounted for using the sum-of-fractions method described in the following procedure. The only sources which may be considered insignificant (and not included in the sum-of-fractions) are:

- Gammas with energies below 0.3 MeV,
- All pure beta emitters with peak energies below 0.3 MeV,
- Pure beta emitters with peak energies above 0.3 MeV when the combined source of all such betas is under 2×10^{12} β/sec.

- Beta emissions from gamma-emitting isotopes.

Table 1 - Payload Source Strength and Source Strength Density Limits

Energy (MeV)	General Sources		Discrete Sources (shored at centroid)*		
	Source γ/sec	Source Density γ/sec·g	Source γ/sec	Source Density γ/sec·g	
				2.5 ft³	55 gal
	❶	❷	❸	❹	❺
3.50	7.903E+09	3.502E+05	2.227E+11	2.378E+06	1.260E+06
2.75	1.045E+10	5.471E+05	3.001E+11	3.696E+06	1.961E+06
2.25	1.477E+10	8.879E+05	4.136E+11	5.789E+06	3.085E+06
1.83	2.426E+10	1.701E+06	5.774E+11	1.071E+07	5.745E+06
1.50	4.776E+10	3.988E+06	8.307E+11	2.410E+07	1.301E+07
1.17	1.641E+11	1.092E+07	1.426E+12	7.866E+07	5.217E+07
0.90	8.629E+11	3.447E+07	2.513E+12	2.538E+08	1.578E+08
0.70	1.815E+12	1.164E+08	4.407E+12	8.365E+08	4.999E+08
0.50	6.237E+12	7.702E+08	1.058E+13	5.318E+09	3.103E+09
Co-60	1.073E+11	7.997E+06	1.236E+12	5.713E+07	3.303E+07
Cs-137	2.305E+12	1.556E+08	5.158E+12	1.145E+09	6.549E+08

**For discrete source limits, use columns ❸ and ❹ when the payload object meets the 2.5 ft³ size criteria, or columns ❸ and ❺ when it meets the 55 gallon size criteria. When the size meets neither criteria use columns ❶ and ❷.*

Qualification Procedure

The Payload Qualification Flowchart (Figure 1) provides a graphical overview of the qualification process. The procedure below provides more detailed step-wise instructions.

1. Determine the number of types of material (payload items) in the payload. For each item, determine the configuration (i.e., general or discrete), isotopic source strength (in γ/sec), isotopic source strength density (in γ/sec·g for the hottest portion of the payload item), dimensions, volume, mass, and maximum mass density. Determine the payload totals for each parameter.

2. For payloads that include pure beta emitters with maximum beta energies > 0.3 MeV and $\sum S_\beta \geq$ 2E+12 β/sec, convert each beta source to an equivalent gamma source for each payload item.

   - Confirm that no isotope peak beta energies are > 3.5 MeV; materials with beta energies > 3.5 MeV are unacceptable.
   - The equivalent gamma source for each payload item, S_γ, equals 3.5E-04 S_β Z_w $E_{\beta avg}$ in gammas per sec; where:
     S_β is the beta source strength in β/sec ,
     Z_w is the weighted average Z of the beta-absorbing material; for a single material absorber, use the Z of the material, for compounds or mixtures, use a weighted average Z_w:

     $$Z_W = \sum_{i=1}^{n} \left(\frac{m_i}{m_{total}} \cdot Z_i \right)$$

     Z_w is determined, as described above, for both the waste payload and the wall of the secondary container (liner) that the waste resides in, the higher of the two Z_w values is used, and
     $E_{\beta avg}$ is the <u>average</u> energy of the beta in MeV.

   - The resulting equivalent gamma source has strength S_γ at an energy of $E_{\beta max}$, the <u>maximum</u> beta energy.
   - Include the equivalent gamma source along with the other gamma source(s) determined in Step 3.
   - Equivalent gamma energies must be rounded up to the next higher energy level listed in Table 1.

3. For each gamma energy of each payload item (ignoring gamma energies below 0.3 MeV), calculate the total γ/sec for the payload item <u>and</u> the γ/sec·g for the hottest (highest source strength density) portion of the item.

   - ^{60}Co and ^{137}Cs may be treated like single "energies" since they have their own limits in Table 1.
   - Gamma energies must be rounded up to the next higher energy level listed in Table 1.

- If any gammas have energies above 3.5 MeV, the material is unacceptable for transport in the package.
- For payloads with a large number of gammas, the gammas may be grouped into the energy groups in Table 1 and the total gamma sources can be determined for each group. The energies listed in Table 1 are the maximum energies for the groups.
- Calculations of γ/sec·g should not include the mass of liners or other secondary containers.

4. For each payload item, select the two appropriate limit columns (❶ through ❺) in Table 1: one each for γ/sec and γ/sec·g. Base the γ/sec on the total γ/sec for the item, and the γ/sec·g on the highest source strength density ("hottest") portions of the item.
   - Confirm that the density of each payload item is less than 9.0 g/cm^3. Items with higher densities can only be qualified using the γ/sec limits because the γ/sec·g limits are not valid for $\rho \geq 9.0$ g/cm^3.
   - For "discrete" sources, confirm that the sources meet the shoring requirement and the volume and the physical dimension specifications listed in the beginning of this Attachment.
   - Crud/contamination (or powder) payload items can only be qualified using the γ/sec limits (Table 1, column ❶ or ❸).
5. For each energy, calculate the γ/sec and γ/sec·g fractions (i.e., payload item source/limit fraction). Select the <u>smallest</u> of each pair of fractions at each energy and add the resulting fraction to the running sum of fractions.
6. Repeat Steps 4-5 for each payload item, adding the fractions to the running sum.
7. If the sum-of-fractions is less than 0.95, the payload's radiological source is acceptable.

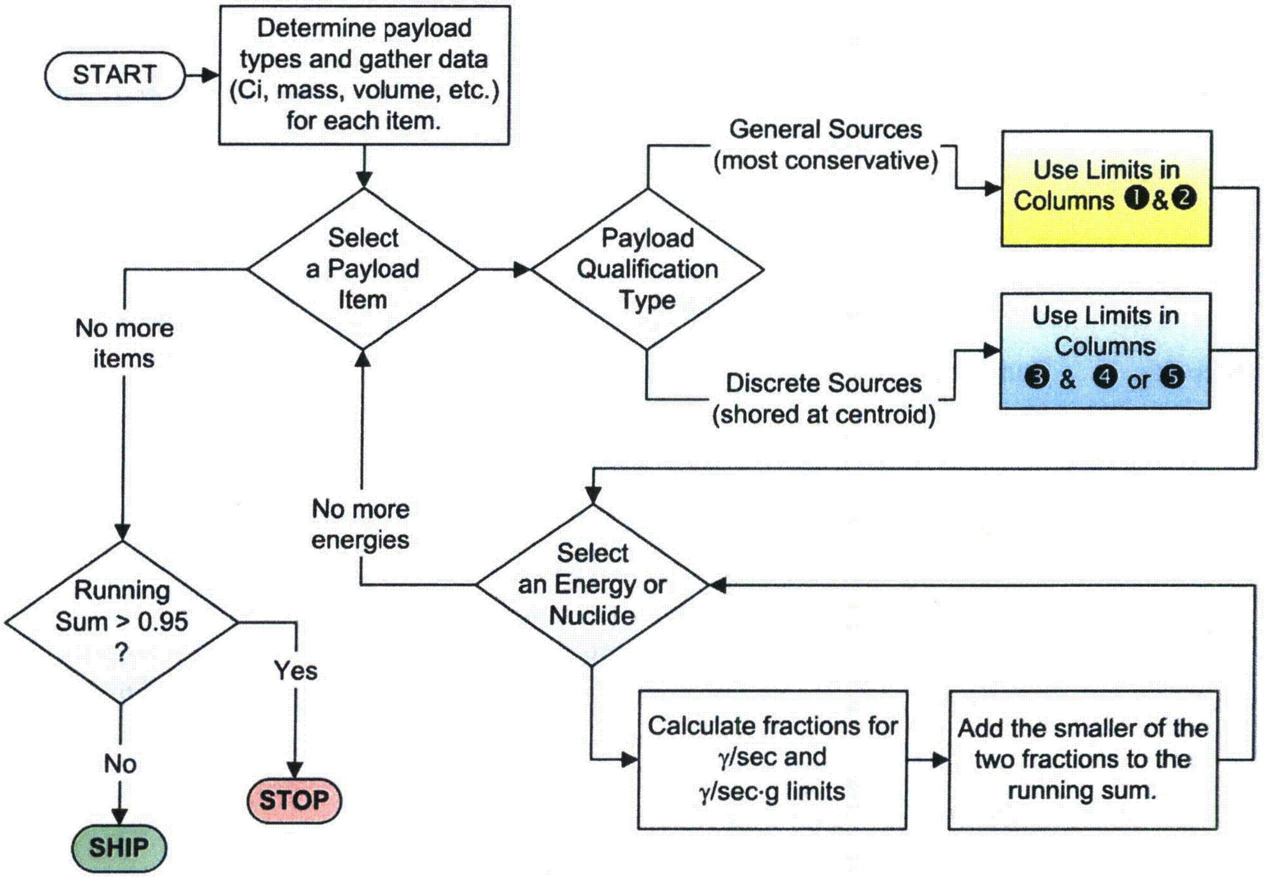


Figure 1 – Payload Qualification Flow Chart

Example 1 - Cs-137 Source Capsule

Problem: Determine the acceptability of a 50 Ci ^{137}Cs source to be centrally shored. The source is a metal capsule 2 cm in diameter by 10 cm long, and the Cs source pellet weighs 50 g.

Step 1: Characterize Source

Given in the problem statement.

Step 2: Convert Beta Source to Equivalent Gamma Source

Not applicable (Cs-137 is not a pure beta emitter).

Step 3: Calculate Gamma Source Strengths and Source Strength Densities

The qualification Table has specific limits for ^{137}Cs, so it is not necessary to do the qualification by energy line. The source's Ci source strength must be converted to γ/sec and γ/sec·g in order to calculate the source/limit fractions. ^{137}Cs produces 0.85 gammas per decay with an energy of 0.66 MeV. The total source strength is

$$3.7\times10^{10}\frac{d}{Ci}\times\frac{0.85\gamma}{d}\times 50Ci = 1.57\times10^{12}\frac{\gamma}{\sec},$$

and, dividing by 50 g, the total source strength density is 3.14E10 γ/sec·g.

Step 4: Select the Limits

Since this payload is to be shipped in a shored configuration, the payload is a "discrete" type payload. The size fits within the defined envelope for the 2.5 ft^3 payload, therefore the column ❸ and ❹ limits apply for γ/sec and γ/sec·g, respectively.

Steps 5-7 Sum the Fractions

For this example, there is only one fraction to calculate[2].

Line	Payload Item	Type	Shape (Discrete Only)	Energy (MeV),or Nuclide	Payload Source Term		Limits			Fractions, F		F_{min}
					γ/sec	γ/sec·g	Energy	γ/sec	γ/sec·g	γ/sec	γ/sec·g	
1	Source	Discrete	2.5 ft3	Cs-137	1.57E+12	3.15E+10	Cs-137	❸ 5.16E+12	❹ 1.14E+09	3.05E-01	2.75E+01	3.05E-01
											Sum:	3.05E-01

Since the sum is less than 0.95, the source is an acceptable payload.

[2] Always perform calculations with the full precision for the limits shown in Table 1. In these examples, full precision data was used, but the number of digits is reduced for presentation purposes.

Example 2 – Solidified Process Waste

Problem: Determine the acceptability of a 100 ft^3 secondary container containing solidified process waste. The activity is uniformly distributed. The measured weight of the filled container is 13,100 lbs, and the weight of the empty container is 1,100 lbs. The isotopic activity, determined by analysis of samples of the waste, is:

5 Ci of ^{60}Co, 10 Ci of ^{137}Cs, 50 Ci of ^{55}Fe, 4 Ci of ^{54}Mn, and 20 Ci of ^{90}Sr

Step 1: Characterize Source

Given in the problem statement.

Step 2: Convert Beta Source to Equivalent Gamma Source

^{90}Sr emits beta radiation through its own decay, plus the decay of its short-lived daughter product, ^{90}Y. So the beta production rate is 20 Ci * 3.7E+10 d/Ci *2 = 1.5E+12 β/sec. Since this is below the threshold of 2E+12 β/sec, the beta production is not significant and can be disregarded.

Step 3: Calculate Gamma Source Strengths and Source Strength Densities

The qualification Table has specific limits for ^{60}Co and ^{137}Cs, but it will be necessary to do the qualification by energy line for the remaining nuclides. After converting the Ci data to gamma energy lines for the remaining nuclides (neglecting any gamma energy lines < 0.3 MeV), the following source data are to be used for qualification. The γ/sec·g source strength densities are based on 12,000 lbs, the actual weight of the radioactive material. The mass density is assumed to be uniform for the payload.

Energy (MeV),or Nuclide	Payload Source Term	
	γ/sec	γ/sec·g
Co-60	3.70E+11	6.80E+04
Cs-137	3.15E+11	5.78E+04
0.8348	1.48E+11	2.72E+04

Step 4: Select the Limits

Since this payload does not meet the definition of either of the two discrete shored configurations (2.5 ft^3 or 55 gal), it is a "general" type payload. The limits in columns ❶ and ❷ apply for γ/sec and γ/sec·g, respectively.

Steps 5-7 Sum the Fractions

For this example, there are three lines: a ^{60}Co line, ^{137}Cs line, and one energy line representing ^{54}Mn (^{55}Fe and ^{90}Sr are disregarded because ^{55}Fe gammas are below 0.3 MeV, and the ^{90}Sr betas are below 2E+12 β/sec).

Line	Payload Item	Type	Shape (Discrete Only)	Energy (MeV),or Nuclide	Payload Source Term		Limits					Fractions, F		F_{min}
					γ/sec	γ/sec·g	Energy		γ/sec		γ/sec·g	γ/sec	γ/sec·g	
1	Solidified Waste Cont.	General		Co-60	3.70E+11	6.80E+04	Co-60	❶	1.07E+11	❷	8.00E+06	3.45E+00	8.50E-03	8.50E-03
2	Solidified Waste Cont.	General		Cs-137	3.15E+11	5.78E+04	Cs-137	❶	2.31E+12	❷	1.56E+08	1.36E-01	3.71E-04	3.71E-04
3	Solidified Waste Cont.	General		0.8348	1.48E+11	2.72E+04	0.9	❶	8.63E+11	❷	3.45E+07	1.72E-01	7.89E-04	7.89E-04
													Sum:	9.66E-03

Since the sum is less than 0.95, the container is an acceptable payload.

Example 3 – Dewatered Resin Liner

Problem: Determine the acceptability of a 100 ft^3 steel secondary container containing dewatered resin. The activity is uniformly distributed. The measured weight of the filled container is 13,100 lbs; the weight of the empty container is 1,100 lbs. The isotopic activity, determined by analysis of samples of the waste, is: 5 Ci of ^{60}Co, 10 Ci of ^{137}Cs, 50 Ci of ^{55}Fe, 4 Ci of ^{54}Mn, and 30 Ci of ^{90}Sr. Also included is a 100 gram piece of activated metal, not shored, with an activity of 0.5 Ci of ^{60}Co. The activated metal is steel with a density of 8 g/cm^3.

This differs from Example 2 in that there is more ^{90}Sr, and there is the additional piece of activated metal.

Step 1: Characterize Source

Given in the problem statement.

Step 2: Convert Beta Source to Equivalent Gamma Source

^{90}Sr emits beta radiation through its own decay, plus the decay of its short-lived daughter product, ^{90}Y. So the total beta production rate is 30 Ci * 3.7E+10 d/Ci * 2 = 2.22E+12 betas/sec. Since this is above the threshold of 2E+12 betas/sec, the beta production must be considered. Using the procedure to convert beta into equivalent gamma radiation described in Attachment 1, the $^{90}Sr/^{90}Y$ betas[3] will be treated as follows:

E_{maxSr} = 0.54 MeV, E_{avgSr} = 0.19 MeV

E_{maxY} = 2.27 MeV, E_{avgY} = 0.93 MeV

Z_{Resin} = 5.6, Z_{Steel} = 26

Z_w= 26 (the higher of the resin Z and the liner wall Z)

$S_{\gamma Sr}$ =(1.11E+12)(3.5E-04)(26)(0.19)= <u>1.92E+08 γ/s @ 0.54 MeV</u>

$S_{\gamma Y}$ =(1.11E+12)(3.5E-04)(26)(0.93)= <u>9.39E+09 γ/s @ 2.27 MeV</u>

Step 3: Calculate Gamma Source Strengths and Source Strength Densities

This payload must be broken into two payload items, due to the physical and radiological differences between the resins and the activated metal.

[3] Cember, H., "Introduction to Health Physics," Pergamon Press, 2nd Ed.

Resin Payload Item

Like Example 2, the following source data are to be used for qualification of the gamma emitters. The mass density is assumed to be uniform for the resin portion of the payload.

Energy (MeV),or Nuclide	Payload Source Term	
	γ/sec·g	γ/sec·g
Co-60	3.70E+11	6.80E+04
Cs-137	3.15E+11	5.78E+04
0.8348	1.48E+11	2.72E+04

Activated Metal Payload Item

^{60}Co emits two gammas per disintegration, therefore the total source strength for the activated metal is (0.5 Ci)(2 γ/d)(3.7E+10 d/sec-Ci) = 3.7E+10 γ/sec. Dividing by the mass of 100 g, the source strength density is 3.7E+08 γ/sec. The mass density is assumed to be uniform for the 100 gram piece of metal.

Step 4: Select the Limits

Resin Payload Item - Since this payload item does not meet the definitions of either of the two discrete shored configurations (2.5 ft^3 or 55 gal), it is a "general" type payload. The limits in columns ❶ and ❷ apply for γ/sec and γ/sec·g, respectively.

Activated Metal Payload Item – This payload item is small and fits within the defined envelope for the 2.5 ft^3 payload, however it is not shored, and so the activated metal is also a "general" type payload item. Columns ❶ and ❷ apply for the γ/sec and γ/sec·g limits, respectively.

Steps 5-7 Sum the Fractions

For this example, there are six lines: 1-3 are for the resin gamma emitters, 4-5 are for the bremsstrahlung gammas produced by ^{90}Sr and ^{90}Y, and one line for the activated metal ^{60}Co.

Line	Payload Item	Type	Shape (Discrete Only)	Energy (MeV),or Nuclide	Payload Source Term		Limits					Fractions, F		F_{min}
					γ/sec	γ/sec·g	Energy		γ/sec		γ/sec·g	γ/sec	γ/sec·g	
1	Resin	General		Co-60	3.70E+11	6.80E+04	Co-60	❶	1.07E+11	❷	8.00E+06	3.45E+00	8.50E-03	8.50E-03
2	Resin	General		Cs-137	3.15E+11	5.78E+04	Cs-137	❶	2.31E+12	❷	1.56E+08	1.36E-01	3.71E-04	3.71E-04
3	Resin	General		0.8348	1.48E+11	2.72E+04	0.9	❶	8.63E+11	❷	3.45E+07	1.72E-01	7.89E-04	7.89E-04
4	Resin (betas)	General		0.54	1.92E+08	3.53E+01	0.7	❶	1.82E+12	❷	1.16E+08	1.06E-04	3.03E-07	3.03E-07
5	Resin (betas)	General		2.27	9.39E+09	1.73E+03	2.75	❶	1.05E+10	❷	5.47E+05	8.99E-01	3.15E-03	3.15E-03
6	Metal	General		Co-60	3.70E+10	3.70E+08	Co-60	❶	1.07E+11	❷	8.00E+06	3.45E-01	4.63E+01	3.45E-01
													Sum:	3.58E-01

Since the sum is less than 0.95, the container is an acceptable payload.

Example 4 – Activated Waste with Non-Fixed Contamination

Problem: Determine the acceptability of a 100 ft^3 steel secondary container containing activated metal. The measured weight of the filled container is 7,100 lbs; the weight of the empty container is 1,100 lbs. The metal is composed of mildly activated steel, with non-fixed surface contamination. The contaminated surface area is estimated to be 500 ft^2. There is one small piece of activated steel with a significantly higher activity. Determine whether this smaller item can be included in the shipment, and whether it needs to be shored. The isotopic activities, determined by analysis of samples of the waste, are as follows:

- Most of the steel has similar radiological properties. Based on an analysis of the highest-activity sample, the constituents are: 20 Ci of ^{58}Co, 30 Ci of ^{60}Co, and 20 Ci of ^{54}Mn.
- The small activated metal item has a mass of 100 g, dimensions of 1" x 1" x 24", with an activity of 6 Ci of ^{60}Co.
- The non-fixed crud contamination level, based on the highest-activity sample, is 50,000 dpm, which has been determined to be 50% ^{55}Fe, 30% ^{137}Cs, and 20% ^{60}Co. The contaminated surface area is 500 ft^2.

Step 1: Characterize Source

Given in the problem statement.

Step 2: Convert Beta Source to Equivalent Gamma Source

Not applicable since the beta source is less than 2E+12 β/sec.

Step 3: Calculate Gamma Source Strengths and Source Strength Densities

100g Activated Metal Payload Item

^{60}Co emits two gammas per disintegration, therefore the total source strength for the small activated metal item is (6 Ci)(2 γ/d)(3.7E+10 d/sec-Ci) = 4.44E+11 γ/sec. Dividing by the mass of 100 g, the source strength density is 4.44E+09 γ/sec. The mass density is assumed to be uniform for the small activated metal item.

Energy (MeV),or Nuclide	Payload Source Term	
	γ/sec	γ/sec·g
Co-60	4.44E+11	4.44E+09

Remaining Activated Metal Payload Item

^{60}Co emits two gammas per disintegration, therefore the total ^{60}Co source strength for the activated metal is (30 Ci)(2 γ/d)(3.7E+10 d/sec-Ci) = 2.22E+12 γ/sec. The remaining nuclides, ^{58}Co and ^{54}Mn, were converted to individual energy lines[4] (E<0.3 MeV were neglected). Sources were divided by 2.72E+06 g (i.e., 6,000 lb) to obtain the γ/sec·g. The mass density of the metal is assumed to be uniform. The resulting sources are:

Energy (MeV),or Nuclide	Payload Source Term	
	γ/sec	γ/sec·g
Co-60	2.22E+12	8.16E+05
0.511	2.21E+11	8.12E+04
0.8108	7.36E+11	2.70E+05
0.8348	7.40E+11	2.72E+05
0.8639	5.45E+09	2.00E+03
1.6747	3.97E+09	1.46E+03

Crud Payload Item

50,000 dpm is equivalent to 2.25E-08 Ci per 100 cm^2. The total source strength is therefore (2.25E-08 Ci/100cm^2) (500 ft^2)(929 cm^2/ft^2) = 1.05E-04 Ci. The nuclide breakdown is therefore: 5.23E-05 Ci of ^{55}Fe, 3.14E-05 Ci of ^{137}Cs, and 2.09E-05 Ci of ^{60}Co. ^{55}Fe can be neglected since it does not emit any gammas > 0.3 MeV. We can only use the γ/sec limit for qualification. The source inputs are therefore:

Energy (MeV),or Nuclide	Payload Source Term	
	γ/sec	γ/sec·g
Co-60	1.55E+06	
Cs-137	9.88E+05	

Step 4: Select the Limits

The 100g activated item would meet the size criteria for the 55-gallon discrete shored configuration if both the container were shored and the item was shored within the container, in which case its limits would be columns ❸ and ❺ for γ/sec and γ/sec·g, respectively. Otherwise, since it would be unshored, the limits in columns ❶ and ❷ would apply for γ/sec and γ/sec·g, respectively.

The remaining activated metal does not meet the definitions of either of the two discrete shored configurations (2.5 ft^3 or 55 gal), so it is a "general" type payload item. The limits in columns ❶ and ❷ apply for γ/sec and γ/sec·g, respectively.

The crud is free to move within the cavity and is therefore a "general" type payload item. Also, as discussed in the first section of this Attachment, crud must be qualified using the γ/sec limit. Thus, the limit in column ❶,in γ/sec, applies for the crud.

[4] MicroShield, Version 8.01, Grove Engineering.

Steps 5-7 Sum the Fractions

First we will try qualifying the payload without shoring the small activated item. Note that it is not acceptable to average the activated metal together with the small 100 g item.

Line	Payload Item	Type	Shape (Discrete Only)	Energy (MeV),or Nuclide	Payload Source Term		Limits			Fractions, F		F_{min}
					γ/sec	γ/sec·g	Energy	γ/sec	γ/sec·g	γ/sec	γ/sec·g	
1	100g activated item	General		Co-60	4.44E+11	4.44E+09	Co-60	❶ 1.07E+11	❷ 8.00E+06	4.14E+00	5.55E+02	4.14E+00
2	Remaining metal	General		Co-60	2.22E+12	8.16E+05	Co-60	❶ 1.07E+11	❷ 8.00E+06	2.07E+01	1.02E-01	1.02E-01
3	Remaining metal	General		0.511	2.21E+11	8.12E+04	0.7	❶ 1.82E+12	❷ 1.16E+08	1.22E-01	6.98E-04	6.98E-04
4	Remaining metal	General		0.8108	7.36E+11	2.70E+05	0.9	❶ 8.63E+11	❷ 3.45E+07	8.53E-01	7.84E-03	7.84E-03
5	Remaining metal	General		0.8348	7.40E+11	2.72E+05	0.9	❶ 8.63E+11	❷ 3.45E+07	8.57E-01	7.89E-03	7.89E-03
6	Remaining metal	General		0.8639	5.45E+09	2.00E+03	0.9	❶ 8.63E+11	❷ 3.45E+07	6.31E-03	5.80E-05	5.80E-05
7	Remaining metal	General		1.6747	3.97E+09	1.46E+03	1.83	❶ 2.43E+10	❷ 1.70E+06	1.64E-01	8.58E-04	8.58E-04
8	Crud	General		Co-60	1.55E+06		Co-60	❶ 1.07E+11	❷ 8.00E+06	1.44E-05		1.44E-05
9	Crud	General		Cs-137	9.88E+05		Cs-137	❶ 2.31E+12	❷ 1.56E+08	4.28E-07		4.28E-07
											Sum:	4.26E+00

This approach does not pass. Since the discrete shored payload items have higher limits, we can try to see if shoring the 100g item will pass.

Line	Payload Item	Type	Shape (Discrete Only)	Energy (MeV),or Nuclide	Payload Source Term		Limits			Fractions, F		F_{min}
					γ/sec	γ/sec·g	Energy	γ/sec	γ/sec·g	γ/sec	γ/sec·g	
1	100g activated item	Discrete	55 gal	Co-60	4.44E+11	4.44E+09	Co-60	❸ 1.24E+12	❺ 3.30E+07	3.59E-01	1.34E+02	3.59E-01
2	Remaining metal	General		Co-60	2.22E+12	8.16E+05	Co-60	❶ 1.07E+11	❷ 8.00E+06	2.07E+01	1.02E-01	1.02E-01
3	Remaining metal	General		0.511	2.21E+11	8.12E+04	0.7	❶ 1.82E+12	❷ 1.16E+08	1.22E-01	6.98E-04	6.98E-04
4	Remaining metal	General		0.8108	7.36E+11	2.70E+05	0.9	❶ 8.63E+11	❷ 3.45E+07	8.53E-01	7.84E-03	7.84E-03
5	Remaining metal	General		0.8348	7.40E+11	2.72E+05	0.9	❶ 8.63E+11	❷ 3.45E+07	8.57E-01	7.89E-03	7.89E-03
6	Remaining metal	General		0.8639	5.45E+09	2.00E+03	0.9	❶ 8.63E+11	❷ 3.45E+07	6.31E-03	5.80E-05	5.80E-05
7	Remaining metal	General		1.6747	3.97E+09	1.46E+03	1.83	❶ 2.43E+10	❷ 1.70E+06	1.64E-01	8.58E-04	8.58E-04
8	Crud	General		Co-60	1.55E+06		Co-60	❶ 1.07E+11	❷ 8.00E+06	1.44E-05		1.44E-05
9	Crud	General		Cs-137	9.88E+05		Cs-137	❶ 2.30E+12	❷ 1.56E+08	4.29E-07		4.29E-07
											Sum:	4.79E-01

Since the sum is less than 0.95, the container is an acceptable payload if the container and 100 g item are shored such that the 100g item is located at the centroid of the cask cavity.

Example 5 – Contaminated Soil

Problem: Determine the acceptability of a 100 ft^3 steel secondary container containing a contaminated soil mixture. The activity is not uniformly distributed. The measured weight of the filled container is 10,100 lbs; the weight of the empty container is 1,100 lbs. 5% of the payload mass is made up of small bits of grout used to immobilize contamination. The size of the grout chunks ranges from 0.1 cm to 10 cm. The grout contains ^{137}Cs at a maximum concentration of 210 Ci/ft^3. The remaining 95% of the material is soil with a activity of 10 Ci/ft^3 of ^{137}Cs. The density of the soil and grout are both 100 lb/ft^3. Activities were determined by analysis of samples of the most active representative waste.

Step 1: Characterize Source

Given in the problem statement.

Step 2: Convert Beta Source to Equivalent Gamma Source

Not applicable (Cs-137 is not a pure beta emitter).

Step 3: Calculate Gamma Source Strengths and Source Strength Densities

We will evaluate the payload two ways: one treating the entire payload as a single item with a bounding source strength (γ/sec) and source strength density (γ/sec·g), and the second assuming we will treat the payload as two separate items: grout and soil.

If there is a potential for the contamination to redistribute, then it would be appropriate to qualify the source using only the γ/sec limits. For this example, the grout physically prevents its contamination from redistribution, and for simplicity we assume that the soil, which has a much lower source strength density, also physically binds its contaminants. For both payload items, we will therefore perform the qualification using both source strength (γ/sec) and source strength density (γ/sec·g). Note that this example does account for the possibility that the grout will redistribute (or concentrate) itself within the soil, since the single payload approach will use the higher source strength density (γ/sec·g) of the grout in the qualification.

Grout Payload Item

The grout gamma source strength is (210 Ci/ft^3)(1 ft^3/100 lb)(9,000 lb*0.05)(3.7E+10 d/sec-Ci)(0.85 γ/d) = 2.97E+13 γ/sec. Dividing by the mass (450 lb, or 2.04E+05 g), the source strength density would be 1.46E+08 γ/sec·g.

Energy (MeV),or Nuclide	Payload Source Term	
	γ/sec	γ/sec·g
Cs-137	2.97E+13	1.46E+08

Soil Payload Item

The soil gamma source strength is (10 i/ft^3)(1 ft^3/100 lb)(9,000 lb*0.95)(3.7E+10 d/sec-Ci)(0.85 γ/d) = 2.69E+13 γ/sec. Dividing by the mass (8550 lb, or 3.88E+06 g), the source strength density would be 6.93E+06 γ/sec·g.

Energy (MeV),or Nuclide	Payload Source Term	
	γ/sec	γ/sec·g
Cs-137	2.69E+13	6.93E+06

Combined Grout/Soil Payload Item

If the payload is treated as a single item, the γ/sec is set equal to the sum of the γ/sec for both the grout and soil components. The γ/sec·g is set equal to that of the "hottest" component (i.e., the grout). Thus, the gamma source strength would be 5.66E+13 γ/sec (2.97E+13 + 2.69E+13). The γ/sec·g equals the 1.46E+08 value that applies for the grout.

Energy (MeV),or Nuclide	Payload Source Term	
	γ/sec	γ/sec·g
Cs-137	5.66E+13	1.46E+08

Step 4: Select the Limits

Since none of these payload items meets the definition of either of the two discrete shored configurations (2.5 ft^3 or 55 gal), they are "general" type payload items. The limits in columns ❶ and ❷ apply for γ/sec and γ/sec·g, respectively.

Steps 5-7 Sum the Fractions

As a first try, we attempt to qualify the payload as being two components: the grout and soil.

Line	Payload Item	Type	Shape (Discrete Only)	Energy (MeV),or Nuclide	Payload Source Term		Limits					Fractions, F		F_{min}
					γ/sec	γ/sec·g	Energy		γ/sec		γ/sec·g	γ/sec	γ/sec·g	
1	Grout	General		Cs-137	2.97E+13	1.46E+08	Cs-137	❶	2.31E+12	❷	1.56E+08	1.29E+01	9.36E-01	9.36E-01
2	Soil	General		Cs-137	2.69E+13	6.93E+06	Cs-137	❶	2.31E+12	❷	1.56E+08	1.17E+01	4.46E-02	4.46E-02
													Sum:	9.80E-01

Since the sum is greater than 0.95, the container is not an acceptable payload.

It is acceptable, however, to treat the payload as a single (combined) item, with a γ/sec equal to the sum of the component (grout and soil) γ/sec values, and a γ/sec·g equal to that of the "hottest" component (i.e., the grout).

Line	Payload Item	Type	Shape (Discrete Only)	Energy (MeV),or Nuclide	Payload Source Term		Limits			Fractions, F		F_{min}
					γ/sec	γ/sec·g	Energy	γ/sec	γ/sec·g	γ/sec	γ/sec·g	
1	All-grout	General		Cs-137	5.66E+13	1.46E+08	Cs-137	❶ 2.31E+12	❷ 1.56E+08	2.46E+01	9.36E-01	9.36E-01
											Sum:	9.36E-01

Since the sum is less than 0.95, the container is an acceptable payload.

This example illustrates that there is no benefit from dividing a payload into multiple payload items if all of the items qualify under the γ/sec·g limit. If the payload is divided, one of the (γ/sec·g) fractions will be that which applies for the grout (i.e., 0.936). If the single payload approach is used, the γ/sec·g value is set to that which applies for the "hottest" item (the grout), so the total fraction for the entire payload would be 0.936. Separating small, high source strength density items from the overall payload only helps if those small (low mass) items are qualified under the γ/sec limit, and not the γ/sec·g limit.

Attachment 2
Determination of Hydrogen Concentration

1. Determine the radionuclide concentration in the contents.
For any package containing materials with radioactivity concentration not exceeding that for LSA, ensure the shipment occurs within 10 days of preparation, or within 10 days of venting the secondary container.
For packages which satisfy the previous conditions, go to step 11, otherwise continue with step 2.

2. Determine the secondary package(s) void volume and the cask cavity void volume.

3. Identify the secondary container(s) vent path, if applicable

4. Determine the quantity of hydrogenous contents

5. Determine the G value of the hydrogenous contents per NUREG/CR-6673[5], Section 3.

6. Determine the energy deposition rate in the hydrogenous contents

7. Determine the hydrogen generation rate per NUREG/CR-6673, Section 4.2

8. Determine the effective hydrogen transport rate due to diffusion for the vent path; see NUREG/CR-6673, Section 4.1

9. Determine the shipping time to reach a hydrogen concentration of 5% in the package; see NUREG/CR-6673, Section 4.2.2.1 and Appendix F, Example #4.

10. If the time to reach 5% concentration is more than double the expected shipping time, the shipment meets the hydrogen concentration requirement.

11. Authorize the shipment

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B. L. Anderson et al. *Hydrogen Generation in TRU Waste Transportation Packages* , NUREG/CR-6673, Lawrence Livermore National Laboratory, Livermore, CA, February 2000

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

Acceptance tests for Configurations 1 and 2 have different weld examination and leak tests than Configuration 3. Maintenance is the same for all configurations. Any reference to drawings, either in general or by specific number, means the drawings listed in the CoC.

8.1 ACCEPTANCE TESTS – CONFIGURATIONS 1 AND 2 (CASKS FABRICATED BEFORE APRIL 1, 1999)

Prior to the first use of the 8-120B package fabricated to Configuration 1 or 2, the following tests and evaluations will be performed.

8.1.1 Visual Examination

The package will be examined visually for any adverse conditions in materials or fabrication. Welds shall be examined for compliance to the drawings. Weld integrity shall be verified by visual examination and magnetic particle or dye penetrant. NDE examinations shall be performed by an ASME Certified inspector. Acceptance criteria for NDE shall be according to ASME Code Section III, Div. 1-Section NB5342 or NB5352 as applicable.

8.1.2 Structural Tests

No structural testing is required.

8.1.3 Leak Tests

This test shall be performed prior to acceptance and operation of a newly fabricated package in accordance with ASTM E-427 using a leak detector capable of detecting the applicable leak rates specified in Figures 4.4 and 4.7 in Chapter 4. Calibration of the leak detector shall be performed using a leak rate standard traceable to NIST. The standard's setting shall correspond to the approved leak rates specified in Figures 4.4 and 4.7 in Chapter 4.

All four containment boundary penetrations must be tested.

- The volume above the vent port Stat-O-Seal
- The volume between the drain line plug and interior of the cask
- The annulus between the o-ring seals of the primary lid
- The annulus between the o-ring seals of the secondary lid

All four of these volumes must be evacuated to a minimum vacuum of 20" Hg, and then be pressurized to a minimum pressure of 25 psig with pure dichlorodifluoromethane (R-12) or 1,1,1,2 – tetrafluoroethane (R-134a). Use the detector probe to "sniff" the following areas:

- The vent port penetration on the underside of the primary lid
- Around the head of the cap screw that plugs the drain line
- Interior side of the inner o-ring for the primary lid
- Interior side of the inner o-ring for the secondary lid

Leak detection shall be in accordance with the specifications of ASTM E-427.

Any condition, which results in leakage in excess of the applicable values specified in Figures 4.3 and 4.6 in Chapter 4 shall be corrected.

8.1.4 Component Tests

Gaskets and seals will be procured and examined in accordance with the Energy*Solutions* Quality Assurance Program.

8.1.5 Test for Shielding Integrity

Shielding integrity of the package will be verified by gamma scan or gamma probe methods to assure the package is free of significant voids in the poured lead shield annulus. 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. Remedy for an unacceptable gamma scan include actions such as controlled re-heating of the cask body to melt the lead to remove any voids or streaming paths. This process may be used as long as average metal temperatures are kept below ~800°F. If the remedy could affect more than just the unacceptable area, e.g., re-heating of the cask body, all affected portions will be re-scanned.

8.1.6 Thermal Acceptance Tests

No thermal acceptance testing will be performed on the 8-120B package. Refer to the Thermal Evaluation, Chapter 3.0 of the report.

8.2 ACCEPTANCE TESTS – CONFIGURATION 3 (CASKS FABRICATED AFTER APRIL 1, 1999)

Prior to the first use of an 8-120B package fabricated to Configuration 3, the following tests and evaluations will be performed:

8.2.1 Visual Inspections and Measurements

Throughout the fabrication process, confirmation by visual examination and measurement are required to be performed to verify that the 8-120B packaging dimensionally conforms to the drawing referenced in the current Certificate of Compliance for the 8-120B.

The packaging is also required to be visually examined for any adverse conditions in materials or fabrication that would not allow the packaging to be assembled and operated per Section 7.0 or tested in accordance with the requirements of Section 8.0.

Throughout the fabrication process, the fabricator shall request approval from Energy*Solutions* prior to implementation of any options allowed in the drawing.

8.2.2 Weld Examinations

8.2.2.1 All welding of the Containment Boundary identified on drawing C-110-E-0007 will be done in accordance with ASME Code, Section III, Division I, Subsection ND, except as follows:

a. Due to the geometry of the joint configuration, between Item 17 and 18, NDE of the ¾" bevel groove weld and the 1" bevel groove weld may be done by progressive surface examination utilizing the MT method in lieu of RT or UT.
b. Due to the geometry of the joint configuration, between Item 3 and 5A, NDE of the ¾" v groove weld may be done by progressive surface examination utilizing the MT method in lieu of RT or UT.
c. Due to the geometry of the joint configuration, between Item 3 and 4, NDE of the ¾" v groove weld may be done by utilizing the UT + MT methods in lieu of RT.

8.2.2.2 All welding of Non-Containment Boundary items identified on drawing C-110-E-0007 will be done in accordance with ASME Code, Section III, Division I, Subsection NF (Class 3), except as follows:

a. The Root Pass and the Final Pass of the v groove weld between Item 5A, Cask Bottom Plate and Item 5B, Cask Bottom Plate Outer Ring, shall be done in accordance with ASME Code, Section III, Division I, Subsection NF-5230 by magnetic particle examination (MT) with acceptance requirements of ASME Code, Section III, Division I, Subsection NF, Article NF-5340.
b. The Root Pass and the Final Pass of the bevel groove weld between Item 5B, Cask Bottom Plate and Item 1, Outer Cask Shell, shall be done in accordance with ASME Code, Section III, Division I, Subsection NF-5230 by magnetic particle examination (MT) with acceptance requirements of ASME Code, Section III, Division I, Subsection NF, Article NF-5340.

8.2.2.3 Welding on lifting and tiedown lugs identified on drawing C-110-E-0007 will be done in accordance with ASME Code, Section III, Division I, Subsection NF (Class 3) and shall be inspected by magnetic particle examination (MT) with acceptance requirements of ASME Code, Section III, Division I, Subsection ND, Article ND-5340 or NF, Article NF-5340. Inspection shall be before and after 150% load test.

8.2.3 Structural and Pressure Tests

A pressure test of the containment system will be performed as required by 10CFR71.85. As determined in Section 3.4.4, the maximum normal operating pressure for the cask cavity is 35 psig; therefore the minimum test pressure will be 1.5 x 35 = 52.5 psig. The hydrostatic test pressure will be held for a minimum of 10 minutes prior to initiation of any examinations. Following the 10 minute hold time, the cask body, lid and lid/body closure shall be examined for leakage. Any leaks, except from temporary connections, will be remedied and the test and inspection will be repeated. After depressurization and draining, the cask cavity and seal areas will be visually inspected for cracks and deformation. Any cracks or deformation will be remedied and the test and inspection will be repeated.

8.2.4 Leakage Tests

8.2.4.1 General requirements
- Testing method – Per ANSI N-14.5 in accordance with ASTM E-427 if using a halogen leak detector or ASTM E-499 if using a helium leak detector.
- Test Sensitivity – the test method must be capable of meeting the appropriate sensitivity requirements specified in Figures 4.4 or 4.7 in Section 4.0. Calibration of the leak detector shall be performed using a leak rate standard traceable to NIST.

- The leak standard's setting shall correspond to the approved leak test rate (see Section 4.0).
- Any condition, which results in leakage in excess of the maximum allowable leak rate specified in Figures 4.3 or 4.6 (depending on the test gas used), shall be corrected and re-tested.

8.2.4.2 Testing of the entire containment boundary will be performed prior to lead pour to allow access to all containment welds. The containment boundary includes: the inner shell, the cask bottom base plate (BOM 5A), the bolting ring, the lids, the O-ring seal plates of both lids, the inner O-ring of both lids, and the vent port cap screw and its seal.

- (Optional) Insert the sealed metal cavity filler canister into the cask cavity. Verify the canister does not obstruct the vent penetration. The metal must be chemically compatible with the cask liner and the test gas.
- Assemble the cask lids per Section 7.1.
- Evacuate the cask cavity to 20" Hg vacuum, minimum (sealed metal cavity filler canister may be used within the cask cavity)
- Pressurize the cask cavity to a minimum pressure of:
  1) 25 psig with pure 1,1,1,2 – tetrafluoroethane (R-134a),
     or
  2) 1 psig with pure helium.
- Check for leakage of the inner shell and base plate components
- Measure the leakage of the inner (containment) O-ring via the test port in each lid.
- Check for leakage at the vent port.

8.2.5 Component and Material Tests

Energy*Solutions* will apply its USNRC approved 10CFR71 Appendix B Quality Assurance Program, which implements a graded approach to quality based on a component's or material's importance to safety to assure all materials used to fabricate and maintain the 8-120B are procured with appropriate documentation which meet the appropriate tests and acceptance criteria for packaging materials.

This includes as example:
ASTM steel material used for shells, lids, bolts, etc. will comply with and meet ASTM manufacturing requirements.
Seals will meet requirements of ES-C-038, which is included in Appendix 8.3.6.
The impact limiter foam will meet the requirements of ES-M-175, which is included in Appendix 8.3.6.

8.2.6 Shielding Tests

Shielding integrity of the package will be verified by gamma scan to assure the package lead layer meets or exceeds the minimum thickness specified on the cask drawing. All gamma scanning will be performed on a 4-inch square or less grid system. The acceptance criteria (maximum dose rate value) will be determined by: Option 1) measurement of the maximum dose rate value using a test block, which has shield layers that replicate the cask geometry per the drawing, using the gamma scan source and reproducing the source/shield/detector geometry that will be used during the scan of the cask, or Option 2) calculation of the maximum dose rate value using detailed modeling software (MCNP or equivalent) incorporating the specific cask dimensions from the drawing and the source/shield/detector geometry applicable to the gamma scan. Any location on the cask which shows a gamma scan dose rate value greater than the maximum dose rate value will be identified as unacceptable. All unacceptable areas will be remedied and re-scanned. Remedy for an unacceptable gamma scan include actions such as controlled

re-heating of the cask body to melt the lead to remove any voids or streaming paths. This process may be used as long as average metal temperatures are kept below ~800°F. If the remedy could affect more than just the unacceptable area, e.g., re-heating of the cask body, all affected portions will be re-scanned.

8.2.7 Thermal Tests

No thermal acceptance testing will be performed on the 8-120B packaging. Refer to the Thermal Evaluation, Section 3.0 of this report.

8.2.8 Miscellaneous Tests

No miscellaneous testing will be performed on the 8-120B packaging.

8.3 MAINTENANCE PROGRAM

Energy*Solutions* operates an ongoing preventative maintenance program for all shipping packages. The 8-120B package will be subjected to routine and periodic inspection and tests as outlined in this section and the approved procedure based on these requirements. Defective items are replaced or remedied, including testing, as appropriate.

Examples of inspections performed prior to each use of the cask include:

Cask Seal Areas: O-rings are inspected for any cracks, tears, cuts, or discontinuities that may prevent the O-ring from sealing properly. O-ring seal seating surfaces are inspected to ensure they are free of scratches, gouges, nicks, cracks, etc. that may prevent the O-ring from sealing properly. Defective items are replaced or remedied, as appropriate and tested in accordance with Section 8.3.2.

Cask bolts, bolt holes, and washers are inspected for damaged threads, severe rusting or corrosion pitting. Defective items are replaced or remedied, as appropriate.

Lift Lugs and visible lift lug welds are inspected to verify that no deformation of the lift lug is evident and that no obvious defects are visible. Defective items are replaced or remedied, as appropriate and tested in accordance with Section 8.2.2.5.

8.3.1 Structural and Pressure Tests

No routine or periodic structural or pressure testing will be performed on the 8-120B packaging.

8.3.2 Leakage Tests

8.3.2.1 Periodic and Maintenance Leak Test.

The 8-120B packaging shall have been leak tested as described below within the preceding 12-month period before actual use for shipment and after maintenance, repair (such as weld repair), or replacement of components of the containment system.

The 8-120B packaging seals shall have been replaced within the 12-month period before actual use for shipment.

General requirements

- Testing method – Per ANSI N-14.5 in accordance with ASTM E-427 if using a halogen leak detector or ASTM E-499 if using a helium leak detector.
- Test Sensitivity – the test method must be capable of meeting the appropriate sensitivity requirements specified in Figures 4.4 or 4.7 or in Section 4.8. Calibration of the leak detector shall be performed using a leak rate standard traceable to NIST.
- The leak standard's setting shall correspond to the approved leak test rate (see Section 4.0).
- Any condition, which results in leakage in excess of the appropriate maximum allowable leak rate specified in Figures 4.3, 4.6 or Section 4.8, shall be corrected and re-tested.

Testing of the Lids and Vent

- (Optional) Insert the sealed metal cavity filler canister into the cask cavity. Verify the canister does not obstruct the vent penetration. The metal must be chemically compatible with the cask liner and the test gas.
- Assemble the cask lids per Section 7.1.
- Evacuate the cask cavity to 20" Hg vacuum (minimum) or 90% vacuum for the leak tight test.
- Pressurize the cask cavity to a minimum pressure of:
  1) 25 psig with pure 1,1,1,2 – tetrafluoroethane (R-134a),
     or
  2) 1 psig with pure helium.
- Measure the leakage of the inner (containment) O-ring via the test port in each lid.
- Measure the leakage of the vent port.

Testing of the Lids – Optional Method

- Assemble the cask lids per Section 7.1.
- Connect to the O-ring test port on the lid and evacuate the annulus between the cask lid O-rings to 20" Hg vacuum (minimum)
- Pressurize the O-ring annulus to a minimum pressure of 25 psig with pure 1,1,1,2 – tetrafluoroethane (R-134a),
- Check for leakage of the inner (containment) O-ring by moving a detector probe along the interior surface of the inner seal according to the specifications of ASTM E-427.

Testing of the Vent – Optional Method

- Assemble the cask Vent Port Cap Screw and Seal per Section 7.1.
- With the vent port cover (Item 30) removed, connect to and evacuate the volume above (lid exterior) the Vent Port Cap Screw and Seal (Items 26 and 27) to 20" Hg vacuum (minimum)
- Pressurize the volume to a minimum pressure of 25 psig with pure 1,1,1,2 – tetrafluoroethane (R-134a),
- Check for leakage of the Vent Port Cap Screw and Seal by moving a detector probe along the interior surface of the Primary Lid in the area of the vent port according to the specifications of ASTM E-427.

The requirements for Periodic and Maintenance Leak Testing of the 8-120B are summarized in Table 8.1.

Table 8.1
Periodic and Maintenance Leak Test of 8-120B

Component	Test Gas	Max. Leak Rate	Minimum Sensitivity	Test Pressure	Procedure	Alternate Procedure
Lid	R-134a	Fig. 4.3	Fig. 4.4	Evacuate cask cavity to 20" Hg then pressurize to 25 psig.	After pressurizing the cask cavity with the test gas, check for gas leakage from the cask Lid inner O-ring using the cask Lid test port.	After pressurizing between the lid O-ring annulus with the test gas, check for gas leakage from the cask Lid inner O-ring using a detector probe.
	Helium	Fig. 4.6	Fig. 4.7	Evacuate cask cavity to 20" Hg, or 90% vacuum for the leak tight test, then pressurize to 1 psig.	After pressurizing the cask cavity with the test gas, check for gas leakage from the cask Lid inner O-ring using the cask Lid test port.	N/A
Vent Port	R-134a	Fig. 4.3	Fig. 4.4	Evacuate cask cavity to 20" Hg then pressurize to 25 psig.	After pressurizing the cask cavity with the test gas, check for gas leakage from the Vent Port and Seal.	After pressurizing the volume above the Vent Port Cap Screw and Seal with the test gas, check for gas leakage from the vent penetration on the inner side of the lid using a detector probe.
	Helium	Fig. 4.6	Fig. 4.7	Evacuate cask cavity to 20" Hg, or 90% vacuum for the leak tight test, then pressurize to 1 psig.	After pressurizing the cask cavity with the test gas, check for gas leakage from the Vent Port Cap Screw and Seal.	N/A

8.3.2.2 Pre-Shipment Leak Test

a. This test is required before each shipment of Type B material quantities. The test will verify that the containment system has been assembled properly.

Note: The pre-shipment leak test is not required before a shipment if the contents meet the definition of low specific activity materials or surface contaminated objects in 10CFR71.4, and also meet the exemption standard for low specific activity materials or surface contaminated objects in 10CFR71.14(b)(3)(i).

b. The test will be performed by pressurizing the annulus between the O-ring seals of each lid, or inlet to the vent port with dry air or nitrogen.

Note: The pre-shipment leak test is typically performed using a test manifold that may be constructed from tubing, fittings, isolation valves and a pressure gauge. Any test apparatus used for this test must have an internal volume, with isolation valves closed and the apparatus connected to the test port location, of less than or equal to 10 cm^3 to achieve the required test sensitivity for the hold time specified in Section 8.3.2.2.d.

Note: If air is used for the test, the air supply should be clean and dry. If it is not, or if the quality of the air supply is uncertain, the test should be performed with nitrogen to ensure reliable results.

c. The test shall be performed using a pressure gauge, accurate within 1%, or less, of full scale.

d. The test pressure shall be applied for at least 15 minutes for the lid or vent port. A drop in pressure of greater than the minimum detectable amount shall be cause for test failure. The maximum sensitivity of the gauge shall be 0.1 psig.

e. Sensitivity at the test conditions is equivalent to the prescribed procedure sensitivity of 10^{-3} ref-cm^3/sec based on dry air at standard conditions as defined in ANSI N14.5-1997.

Table 8.2 summarizes pre-shipment leak test requirements for the 8-120B:

Table 8.2
Pre-Shipment Leak Test of 8-120B Components

Component	Hold Time	Procedure
Lid	15 min.	Connect test manifold to the test port. Pressurize void between O-rings with the test gas, close the isolation valves and hold for the minimum hold time. A drop in pressure of greater than the minimum detectable amount shall be cause for test failure.
Vent Port	15 min.	Remove the threaded cap covering the vent port. Connect test manifold to the vent port. Pressurize the seal and head of the vent port cap screw for the minimum hold time. A drop in pressure of greater than the minimum detectable amount shall be cause for test failure.

8.3.3 Component and Material Tests

Cask seals (O-rings) are inspected each time the cask lids or vent port cap screw are removed. Inspection and replacement of the seal is discussed in Section 8.3.

New seals are lightly coated with a lightweight lubricant such as Parker Super O-Lube or equivalent prior to installation. The lubricant will minimize deterioration or cracking of the elastomer during usage and tearing if removal from the dovetail groove is necessary for inspection. Coating the exposed surfaces of installed lid seals with the lightweight lubricant immediately prior to closing the lid can help to minimize deterioration or cracking of the seal during use. Excess lubricant should be wiped off before closing the lid.

Painted surfaces, identification markings, and match marks used for closure orientation shall be visually inspected to ensure that painted surfaces are in good condition, identification markings are legible, and that match marks used for closure orientation remain legible and are easy to identify.

Visible cask external and cavity welds shall be inspected within twelve months prior to use to verify that the welds specified by the applicable cask drawing are present and that no obvious weld defects are visible. If paint is covering these welds, the inspection may be completed without removing the paint.

8.3.4 Thermal Tests

No periodic or routine thermal testing will be performed on the 8-120B packaging.

8.3.5 Miscellaneous Tests

8.3.5.1 Repair of Bolt Holes

Threaded inserts may be used for repair of bolt holes. The following steps shall be performed for each repair using a threaded insert.

a. Install threaded insert(s), sized per manufacturer's recommendation, per the manufacturer's instructions.

b. At a minimum, each repaired bolt hole(s) will be tested for proper installation by assembling the joint components where the insert is used and tightening the bolts to their required torque value.

Note: If the repair is to bolt holes for lifting components, then a load test will also be performed to the affected components equal to 150% of maximum service load.

c. Each threaded insert shall be visually inspected after testing to insure that there is no visible damage or deformation to the insert.

8.3.6 APPENDICES

8.3.6.1 Appendix

Polyurethane Foam Specification ES-M-175
(available on request)

8-120B Seal Specification ES-C-038
(available on request)

ENERGYSOLUTIONS

AFFIDAVIT
SUBMITTED BY ENERGYSOLUTIONS
CONCERNING CONFIDENTIAL INFORMATION AND TRADE SECRETS

STATE OF SOUTH CAROLINA]
] *ss.*
COUNTY OF LEXINGTON]

I, James R. Carlson II, depose and say that I am duly authorized to make this affidavit, and have reviewed or caused to have reviewed the information which is identified below as proprietary. The following documents and corresponding data files, which are included with our submittal letter EL&P-028-12, SAR changes for the 8-120B Package, contains proprietary information that should be withheld from public disclosure:

Proprietary Calculations, which contains the following proprietary documents and corresponding data files:

ST-551, Rev. 3
ST-625 Rev. 0
ST-596 Rev. 1
ST-618 Rev. 1
NU-391 Rev.5

I have personal knowledge of the criteria and procedures utilized by Energy*Solutions* in designating information as a trade secret or as confidential information of a commercial or financial nature. These calculations contain unique information and methods that have been developed by the Energy*Solutions'* staff for the evaluation of transportation packaging. These methods are considered confidential information that includes Company trade secrets incorporated into such evaluation processes. The proprietary information submitted to the Commission contains the type of information Energy*Solutions* regards as protected and of the type not to be disclosed to unauthorized persons.

The information designated here as proprietary is not available from public sources. Public disclosure of this information would cause substantial harm to the competitive position of Energy*Solutions*. The Company has made substantial investments in salaries and capital equipment and has committed to refine and improve Energy*Solutions*' radioactive waste management system. Competitors of Energy*Solutions* would have great difficulty in duplicating the methods developed by Energy*Solutions*, due not only to the financial investment of Energy*Solutions*, but also to the unique skills, talents, and expertise of Energy*Solutions* employees who have developed these concepts. Disclosure of this information could cause Energy*Solutions* to lose the financial opportunity and business associated with this and other projects similar in nature.

James R. Carlson II
Global Commercial Group Application Engineering Manager (Technology, Engineering & Services)

STATE OF SOUTH CAROLINA]
] *ss.*
COUNTY OF LEXINGTON]

On this 10th day of August 2012, before me, a Notary Public in and for the State of South Carolina, duly commissioned and sworn, personally appeared James Carlson, Engineering Manager for Energy*Solutions*, and on oath stated that he was authorized to make this affidavit on behalf of the corporation.

IN WITNESS WHEREOF, I have set my hand and affixed my official seal the day and year first above written.

SANDRA E. PAYNE
NOTARY PUBLIC
STATE OF SOUTH CAROLINA
My Comm. Expires May 7, 2014

Notary Public, State of South Carolina