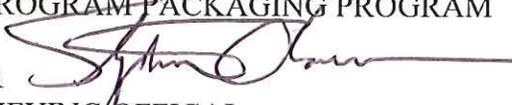




**Department of Energy**  
Washington, DC 20585

JUL 30 2012

MEMORANDUM FOR BRIAN R. HERMANN  
MANAGER, DEFENSE PROGRAM PACKAGING PROGRAM

FROM: STEPHEN C. O'CONNOR   
HEADQUARTERS CERTIFYING OFFICIAL  
DIRECTOR, OFFICE OF PACKAGING AND  
TRANSPORTATION

SUBJECT: Revision 12 to DOE CoC USA/9977/B(M)F-96 (DOE)

Per the June 7, 2011, request from Paul Mann, attached is Revision 12 of Department of Energy (DOE) Certificate of Compliance (CoC) USA/9977/B(M)F-96 (DOE) for the 9977 and its Safety Evaluation Report. This revision is being issued to approve the request for the addition of a new source content envelope for plutonium oxides in a dual DOE-STD 3013 container configuration.

This revision also approves the option to use the seal sensor feature of the DOE ARG-US Radiofrequency Identification (RFID) tag as a Tamper-Indicating Device (TID) see attached "DOE Packaging Certification Program Qualification/Accreditation of ARG-US RDID Tag as a TID Seal."

The expiration date of Revision 12 is October 31, 2012.

If you have any questions, please contact me or Dr. James M. Shuler of my staff at (301) 903-5513.

Attachments

cc w/att.:  
Yung Li, ANL  
Steve Bellamy, SRNS



## Department of Energy

Washington, DC 20585

### DOE Packaging Certification Program Qualification/Accreditation of ARG-US RFID Tag as a TID Seal

July 30, 2012

#### Background

The Nuclear Regulatory Commission (NRC) requires licensees possessing special nuclear material (SNM) to comply with requirements in 10 CFR 71, 73 and 74. The NRC generally accepts tamper indicating (TID) seals for use in complying with the requirements in 10 CFR 71.43, 10 CFR 73, 10 CFR 74.31, 74.33, 74.43, and 10 CFR 74.51 through 74.59. The function of a TID seal in the context of Material Control and Accounting (MC&A) of special nuclear material in 10 CFR 74 is to ensure that a container or vault is properly closed and secured against accident opening, authorized but undocumented opening, or unauthorized opening.

NRC Regulatory Guide (RG) 5.80 "Pressure-Sensitive (PS) and Tamper-Indicating Device Seals for Material Control and Accounting (MC&A) of Special Nuclear Material," December 2010 describes a number of improved TIDs and PS seals developed in recent years, primarily in response to commercial interests outside the nuclear industry. The RG distinguishes between genuine and nongenuine manufactured seals and stresses serial number identification to aid in the control of material or to alert shipping and receiving personnel to containers that were opened in transit. The guide also incorporates recommendations for ensuring that TIDs are properly applied.

RG 5.80 discusses seal limitations and states "*The most successful methods used to attack sealing system are those that exploit the weaknesses of the sealing system rather than the tamper-indicating seal itself. A sealing system would fail at the seal if it could be opened and reclosed without leaving any indications of tampering. All tamper-indicating seals, including PS seals, can be defeated given adequate time and resources. In the context of MC&A, the question is not whether unauthorized persons can defeat the seal, but whether they can defeat it given the available time and resource under the constraints imposed by the conditions of its use.*"

All TID seals are subject to four potential vulnerabilities:

#### (1) Substitution

All seals are vulnerable to being destructively removed and replaced by new seals. Under this scenario, the potential exists for an entire sealed container to be removed (e.g., stolen) and replaced with an identical container (i.e., one that is empty or that contains only low-value materials) bearing a new seal. In this situation TID seals are of value only if the seals used are uniquely identified and this identity cannot be duplicated. Therefore, all users of seals should require assurance from the manufacturer of the seals that they are unique, that they will not be supplied to other users, and that the masters will be controlled. The licensee should take the following precautions: (a) All TID seals should bear a unique logo; (b) seals should be manufactured in a bright, easily recognized color; and (c) all seals should bear a unique serial identification code imprinted by the manufacturer.

#### (2) Removal and Reapplication

TID seals are vulnerable to being removed and reapplied. Clear installation instruction describing proper application and uses of TID seals should always be available.



### (3) Alteration of Label Data

It should not be possible to alter recorded data on the TID or PS seal without the alteration being apparent. Licensees should not rely solely on a seal serial number for container identification because removal or attempted removal of the seal will render the serial number unreadable. In this case, the facility may lose access to information about the contents of the container. Container numbers that are separately marked on containers will help licensees identify the container and its supposed contents even when the seal has been removed or destroyed. Pairing of codes (one on the TID and one on the container) may be used to ensure that TIDs remain attached to the proper container.

### (4) Alteration of Separately Recorded Data

Computerized or hand-written data associated with seals for containers should be controlled to prevent or detect any attempt at unauthorized alteration of that data.

## **ARG-US RFID tag**

ARG-US radio frequency identification (RFID) tag is a battery-powered, active sensor and wireless communication device with automatic alarm capabilities. The tag has a universal form factor for attachment to regulatory-authority-approved transportation containers, as shown below:



The ARG-US RFID tag includes a suite of sensors for seal, shock, temperature, humidity, radiation, and battery strength. The tag also has a non-volatile memory that can record and store encrypted data. Upon installation to a container, the tag can communicate, as well as register events (with time stamps), such as the opening or excessive shock of the container either during routine operation or unauthorized intrusion. Furthermore, verification of presence, or detection of absence, of tags (and containers) can be assured via continuous polling by an interrogator (or reader) controlled by a computer and linked to secured database and web servers in a control center. The sensors have adjustable thresholds for high and low alert/alarm settings; the alerts/alarms are automatic and instantaneous; and the polling intervals are programmable depending on the threat level and security posture, thus providing the state of health (SoH) of the container at all times. The ARG-US RFID system has been thoroughly tested in actual operating environment since 2008 and documented in a series of reports and papers. (See <http://rampac.energy.gov/RFID/RFID.htm>)

## **Comparison of ARG-US RFID Tag Seal with a PS/TID Seal**

Table 1 compares a PS/TID seal and the ARG-US RFID tag seal, with its seal functionality and limitations defined in RG 5.80. The PS/TID seal could be any of those mentioned in RG 5.80; however, it should be noted that the seal sensor in the ARG-US RFID tag is a thin force-sensitive membrane switch which is compressed by a bolt (or a tab) affixing the RFID tag to a container. This is different from the PS seals mentioned in RG 5.80 that are usually applied by adhesives.

Table 1. NRC RG 5.80 for PS and TID Seals

|   | RG 5.80 for PS and TID Seals                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | ARG-US RFID Tag Seal                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|---|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 | The seal should bear a unique serial identity combined with unique information that identifies the licensed facility using the seal. Both the serial identity and the logo or other identifying information should be applied in a manner that makes undetected removal difficult. The licensee should explicitly establish with the manufacturer that it will not sell identical or closely similar seals to any second individual, that it will adequately safeguard print masters, and that it will destroy all printing waste in a manner that would preclude salvage. | Each ARG-US RFID tag has a complex and unique electronic identification assigned by the manufacturer. This identity can be verified at any time wirelessly by the authorized operator. Logo, serial number, and other applicable identifiers are clearly marked and/or engraved on the tag body. The tags, when activated, cannot be removed from the container without triggering a seal sensor alarm. Any tampering will result in the activity being recorded in the tag's non-volatile memory with a time stamp. All other requirements stipulated for the PS/ TID seas described in RG 5.80 are applicable and attainable for the ARG-US RFID tag seal. |
| 2 | The seals should be applied in a manner that ensures that the contents cannot be removed from the sealed container without compromising the integrity of the seal or the container.                                                                                                                                                                                                                                                                                                                                                                                        | Owing to the seal sensor in the ARG-US RFID tag, the contents cannot be removed from a sealed container without triggering an alarm. Additionally, any tampering activity will result in a time-stamped record being generated in the tag's non-volatile memory for subsequent verification.                                                                                                                                                                                                                                                                                                                                                                 |
| 3 | Measurements to determine container contents and the seal application should be coordinated in a manner that ensures that the contents could not be changed between the time when the measurements were made and the seal was applied.                                                                                                                                                                                                                                                                                                                                     | These stipulations can be attained with ARG-US RFID tag seal in exactly the same manner as with PS/ TID seals of RG 5.80.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 4 | For seals used for offsite shipments or for any use where the seal may be exposed to the elements, the seal chosen should be able to withstand such exposure without alteration in a manner that might be confused with tampering or that might destroy any indications of tampering.                                                                                                                                                                                                                                                                                      | The robust construction of the ARG-US RFID tag seal – front plastic cover, back metal plate, and rubber gasket in between – can withstand the elements without changes of appearance or degradation of performance. Possible confusion from weather exposure versus tampering is significantly less likely than with PS/TID seals of RG 5.80.                                                                                                                                                                                                                                                                                                                |
| 5 | Seals should only be available to and only be applied and removed by individuals authorized for that purpose. Written procedures should ensure that individuals authorized to handle seals are properly trained and that they maintain proper records of the seals used, verified, and removed.                                                                                                                                                                                                                                                                            | The administration of ARG-US RFID tag seals, including inventory control and physical application of the tags, can be structured in the same manner as that for the PS/ TID seals of RG 5.80. Qualified administrators/ custodians/operators and approved procedures are the same key elements to success as with PS/ TID seals of RG 5.80.                                                                                                                                                                                                                                                                                                                  |
| 6 | Removed seals should be completely destroyed or should be protected by seal custodians using the same procedures as those for unused seals.                                                                                                                                                                                                                                                                                                                                                                                                                                | ARG-US RFID tag seals, because of its durability and relative high cost, are not usually destroyed after each use. Rather, they are re-initiated and re-logged for the next operation or campaign. When not in use, they are in protected custody just like PS/ TID seals of RG 5.80.                                                                                                                                                                                                                                                                                                                                                                        |
| 7 | Written records of seal use should be maintained.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | This requirement is applicable for, and attainable with, ARG-US RFID tag seals.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |



|                        |                  |                                |              |                     |
|------------------------|------------------|--------------------------------|--------------|---------------------|
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2. PREAMBLE

- 2a. This certificate is issued under the authority of 49 CFR Part 173.7(d).
- 2b. The packaging and contents described in Item 5 below meet the safety standards set forth in subpart E, "Package Approval Standards" and subpart F, "Package, Special Form, and LSA-III Tests" Title 10, Code of Federal Regulations, Part 71.
- 2c. This certificate does not relieve the consignor from compliance with any requirement of the regulations of the U.S. Department of Transportation or other applicable regulatory agencies, including the government of any country through or into which the package will be transported.

|                                                                                                               |                                                                                                                                        |             |
|---------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|-------------|
| 3. This certificate is issued on the basis of a safety analysis report of the package design or application — |                                                                                                                                        |             |
| (1) Prepared by (Name and Address):                                                                           | (2) Title and identification of report or application:                                                                                 | (3) Date:   |
| U.S. Department of Energy<br>Savannah River Operations<br>Office<br>P.O. Box A<br>Aiken, South Carolina 29808 | Safety Analysis Report for Packaging<br>Model 9977 B(M)F-96<br>S-SARP-G-00001, Revision 2, August<br>2007; as supplemented [See 5.(e)] | August 2007 |

4. CONDITIONS

This certificate is conditional upon fulfilling of the applicable Operational and Quality Assurance requirements of 49CFR parts 100 – 199 and 10CFR Part 71, and the conditions specified in Item 5 below.

5. Description of Packaging and Authorized Contents, Model Number, Transport Index, other Conditions, and References:

(a) Packaging

(1) Model Number: 9977

(2) Description:

The 9977 is designed to ship radioactive contents in assemblies of Radioisotope Thermoelectric Generators (RTGs), 3013 Containers, Engineered Containers, or arrangements of nested food-pack cans. The components of the package include the drum, insulation, Containment Vessel (CV), Load Distribution Fixtures (LDFs), and Contents containers. The maximum weight of the packaging is 250 lbs, with a maximum payload of 100 lbs, and a maximum gross weight of 350 lbs.

The drum design meets the performance requirements of 49 CFR 178 for an open head drum, but is modified with a bolted-flange closure. The closure does not incorporate a gasket. The drum body is a closed unit consisting of a shell, top deck plate, reinforcing rim (vertical flange), and a liner assembly, with the volume between the liner assembly and drum shell filled with shock-absorbing thermal-insulating materials. The drum shell and liner are fabricated of 18-gage (0.048-inch) Type 304L stainless steel (SS). The drum shell incorporates a "sanitary" style drum bottom, which incorporates a radiused edge which is butt

|                                   |                                       |
|-----------------------------------|---------------------------------------|
| 6a. Date of Issuance: JUL 30 2012 | 6b. Expiration Date: October 31, 2012 |
|-----------------------------------|---------------------------------------|

FOR THE U.S. DEPARTMENT OF ENERGY

|                                                                                                                                                                           |                                                                                                                           |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|
| 7a. Address (of DOE Issuing Office)<br>U.S. Department of Energy<br>Office of Packaging and Transportation, EM-33<br>1000 Independence Avenue, SW<br>Washington, DC 20585 | 7b. Signature, Name, and Title (of DOE Approving Official)<br><br>Stephen C. O'Connor<br>Headquarters Certifying Official |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|

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welded to the side wall. The drum bottom includes a rolled “wear ring,” 0.060-inch thick by  $\frac{3}{4}$ -inch inside diameter (ID), attached by welds that are external to the drum shell. The drum’s top deck plate is fabricated of  $\frac{3}{16}$ -inch thick Type 304L SS plate. The top portion of the drum incorporates a  $\frac{3}{16}$ -inch thick reinforcing rim (vertical flange) and both reinforces the drum head and protects both the closure lid and the bolts during Hypothetical Accident Condition (HAC) events. The rim includes eight (8) 1-inch diameter drain holes that are qualified as package lifting and tie-down points. Drum construction details are shown on drawings R-R2-G-00017 and R-R2-G-00018. As applicable, the drum is designed, analyzed, and fabricated in accordance with Section III, Subsection NF of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME BPVC), as listed in Table 9.6 of the SARP.

Four (4)  $\frac{3}{4}$ -inch diameter vent holes are drilled at locations around the drum, approximately 90° apart and at each of three elevations, for a total of twelve vent holes along the drum sidewall. Five additional holes, two 1-inch diameter fill holes and three  $\frac{3}{4}$ -inch diameter vent holes are located on the drum bottom. All of the holes are covered with appropriately sized Caplug® fusible plastic plugs. During an HAC fire event, the plugs combust or melt, allowing the drum to vent gases generated by intumescent foam insulation. The vent holes ensure that the drum cannot be ruptured by gas pressure.

The drum closure lid is fabricated from  $\frac{1}{8}$ -inch thick Type 304L SS plate. Eight  $\frac{5}{8}$ -inch by 1 $\frac{1}{4}$ -inch long heavy hex-head bolts with  $\frac{5}{8}$ -inch plain, narrow Type B washers secure the lid to the top deck plate of the drum body. The closure lid incorporates chambers above and below the Lid Plate filled with shock-absorbing thermal-insulating materials. The Lid Top and Lid Bottom chambers are fabricated of 18-gage (0.048-inch) and 14-gage (0.07-inch) Type 304L SS, respectively. The top of the Lid Top is approximately 0.275 inches below the top surface of the drum-head reinforcing rim. The Lid Bottom chamber reinforces the Lid Plate and provides additional thermal protection and shock absorption for the Containment Vessel during HAC events. The Lid Top chamber also reinforces the Lid Plate, adds thermal protection to the contents, and prevents the closure lid from shearing away from the bolts during HAC events.

Four (4)  $\frac{1}{4}$ -inch diameter holes through the Lid Plate allow the Lid Top and Lid Bottom volumes to exchange gases and equilibrate pressure. The Lid Top chamber is vented by four (4)  $\frac{1}{4}$ -inch diameter holes also covered with Caplug® fusible plastic plugs. The Caplugs® prevent water from entering the lid through the vent holes under Normal Conditions of Transport (NCT). In a HAC fire event, the plugs combust or melt, allowing the lid to vent heated air from the Lid Top and Lid Bottom chambers.

To simplify drum-closure operations, the threaded inserts that receive the drum-closure bolts are welded to the underside of the drum’s top deck plate. During installation, the bolts are tightened to a torque value of 45 ( $\pm 5$ ) ft-lb. The bolt heads are drilled through with a  $\frac{1}{8}$ -inch hole to receive Tamper-Indicating Devices (TIDs). Details are shown on Drawing R-R1-G-00020.

Two layers of insulation material fill the volume between the drum liner and shell. First, two  $\frac{1}{2}$ -inch thick blankets of Fiberfrax® insulation are wrapped around and attached to the sides and bottom of the liner. The Fiberfrax® is backed on both

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sides with fiberglass cloth held in place by fiberglass thread stitched longitudinally at 4-inch intervals. The fiberglass cloth gives the Fiberfrax<sup>®</sup> composite both mechanical strength and wear resistance and helps retard gas flow during the HAC fire event. The remaining volume between the Fiberfrax<sup>®</sup> and the drum wall is filled with General Plastics FR-3716 polyurethane foam (also known as Last-A-Foam<sup>®</sup>), poured through fill holes in the drum bottom and foamed in place. The nominal densities of Fiberfrax<sup>®</sup> and FR-3716 foam are 7-to-10 lb/ft<sup>3</sup> and 16 lb/ft<sup>3</sup>, respectively. The thermal-physical properties of Fiberfrax<sup>®</sup> and FR-3716 are listed in Tables 2.9, 2.10, and 3.8 of the SARP. The combined thickness of the two insulators is approximately 4.95 inches radially (i.e., between the liner and the drum shell) and approximately 4.52 inches axially (i.e., between the liner bottom and drum bottom). Details are shown in Drawings R-R1-G-00020, R-R2-G-00017, and R-R2-G-00019.

The closure lid incorporates two chambers of insulation. The Lid Top chamber contains a 1-inch thick, 14-inch diameter disk of Thermal Ceramics Min-K 2000<sup>®</sup> insulation. The Lid Bottom chamber contains a rigid disk of Thermal Ceramics TR-19<sup>®</sup> Block insulation, 4.3-inch thick by 8-inch diameter. When installed, the TR-19<sup>®</sup> disk compresses two (2) 8-inch diameter by ½-inch thick blankets of Fiberfrax<sup>®</sup> insulation to a total thickness of ½ inch. The total axial thickness of both the insulators is approximately 5.75 inches. Details are shown in Drawing R-R2-G-00018.

The 9977 is designed with a CV with a nominal ID of six (6) inches (i.e., the 6CV). The 6CV is a stainless steel pressure vessel designed, analyzed, and fabricated in accordance with Section III, Subsection NB of the ASME Code, with design conditions of 800 psig at 300°F, as listed in Table 9.5 of the SARP. The 6CV is fabricated from 6-inch, Schedule 40, seamless, Type 304L SS pipe (0.280-inch nominal wall). A standard Schedule 40 Type 304L SS pipe cap (also 0.280-inch nominal wall) is welded to the pipe segment to form a blind end. A stayed head is machined from a 7½-inch diameter by 2¼-inch long Type 304L SS bar and is welded to the open end of the pipe segment, completing the vessel body weldment. The head is machined to include 6½-12UNS-2B internal threads and an internal cone-seal surface with a 32-micro-inch finish. Both vessel body joints are Category B, full-penetration, complete-fusion, circumferential welds. A support skirt to stand the 6CV vertically is formed from a short segment of 5-inch, Schedule 40 Type 304L SS pipe welded to the convex side of the cap. Two rectangular notches milled into the bottom edge of the skirt (180° apart) can engage a rectangular key to prevent vessel rotation during removal and installation of the closure assembly.

The 6CV Closure Assembly consists of a Type 304L SS Cone-Seal Plug shaped in part like a truncated cone and a threaded Cone-Seal Nut made from Nitronic 60 SS. The two Closure Assembly components rotate freely relative to one another and are coupled by a snap-ring that also ensures unseating of the closure seal during disassembly. As the Cone-Seal Nut is threaded into the stayed head of the vessel, the Cone-Seal Plug is thrust axially against the corresponding cone-seal surface of the vessel. Both internal and external sealing surfaces are machined to the same angles, surface finishes, and with matching diameters so that they mate with radial clearance of 0.0007 inches. To minimize the potential for thread galling, the Cone-Seal Nut and the Containment Vessel body are made from dissimilar

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materials. Two O-ring grooves (outer and inner) are machined in the face of the external Cone-Seal Plug. Viton<sup>®</sup> GLT/GLT-S O-rings fit into these grooves to complete the leaktight closure assembly.

For operator safety, a 0.094-inch diameter vent hole is located in the stayed head between the threads and the internal sealing surface. The vent hole is clocked 90° from the notches in the vessel support skirt. Unscrewing the Cone-Seal Nut a few turns will unseat the Cone-Seal Plug from the internal cone-seal surface and route any pressurized gases from the CV through the vent hole.

A leak-test port is incorporated into the Cone-Seal Plug and connected by a drilled radial passage to the annular volume between the two O-ring grooves in the Cone-Seal Plug. The leak-test port provides a means of verifying proper assembly of the vessel closure and is itself closed by the Leak-Test Port Plug. The vessel containment boundary is formed by the vessel body weldment, the Cone-Seal Plug, the Leak Test Port Plug, and the Outer O-ring.

The internal volume of a closed 6CV is approximately 608 cubic inches. The nominal assembly weight is 52.3 lb, and the nominal overall length is 24.03 inches. The usable cavity of the 6CV is a minimum of 20.25 inches deep with a minimum diameter of 5.95 inches. Details are shown in Drawing R-R2-G-00042.

The Top and Bottom LDFs are made from 6061-T6 aluminum round bar and fit within the Drum Liner cavity, above and below the 6CV. The LDFs center the 6CV in the liner, stiffen the package in the radial direction, and distribute loads away from the 6CV. The 6CV fits directly into the LDFs. Details are shown in Drawing R-R4-G-00032.

Figure 1 is a Three-Dimensional (3D) Cut Away Illustration of the 9977.

The 9977 is evaluated for shipment of radioactive contents containing Assemblies of Radioisotope Thermoelectric Generators (RTGs), and/or Food-Pack cans, Content C1. Two different sizes of RTGs (the MC2730 and MC3500) can be shipped within a single 9977 configuration. The RTGs are placed within vibration-limiting and thermal-conducting assemblies. One RTG Assembly holds a maximum of four (4) RTGs. Either or both sizes of RTGs may be shipped in the same assembly. The RTG assembly configuration positioned in the 6CV is shown in Figure 2a and 2b.

The term “food-pack” can include metal cans with crimped-seal closures, “slip-lid” closures, or site-specific “convenience containers.” Crimp-sealed food-pack cans are typically fabricated in accordance with Federal Specification PPP-C-96E or equivalent, and meet the size specification as defined by the Can Manufacturers Institute — Voluntary Can Standards. Convenience containers are typically application-specific designs that incorporate screw thread, crimp-sealed, or welded closures. These three types of cans are made typically from tin-plated mild steel or stainless steel.

Actinide oxides and other materials may be placed inside food-pack cans prior to placing items in the packaging. An elastomeric gasket material or polyvinyl chloride tape may be applied to the edge of the can lid. The seal material may limit

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the spread of contamination, but is not credited for any measure of containment within the package.

The can containing the radioactive material is typically placed inside low-density polyethylene or nylon bagging for contamination control. Multiple bags may be present, up to the mass limit for plastics. The bagged inner can is typically then nested within one or more outer cans. The nested assemblies are then placed within the 6CV.

Nesting of food-pack cans is not required (i.e., a single food-pack can is allowed). Food-pack cans may be arranged for handling convenience and contamination control into single, double, or triple-stacked configurations, provided the general requirements listed in Section 1.2.2 of the SARP are satisfied and the food-pack can requirement in Section 1.2.2.2.1 of the SARP is fulfilled.

The 9977 is also evaluated for shipment of radioactive contents from the Addendum [See 5(e)(2)]. Content Envelopes AC.1 through AC.5 include the following: Neptunium metal either as the "Neptunium Sphere" or as metal pieces; the BeRP Ball as a  $^{239}\text{Pu}$  metal sphere in an aluminum heat-sink holder; plutonium and uranium metals; plutonium and uranium metals with a higher  $^{240}\text{Pu}$  limit but with reduced total mass limit; and Highly Enriched Uranium (HEU) metal.

Content Envelopes AC.1 through AC.5 are in solid form as metals. Contents in liquid form are not permitted. Contents are authorized for shipment in 3013 Containers, Food-Pack Cans, and Engineered Containers. These content containers are used to prevent the inadvertent contamination of the package by providing a level of confinement for the radioactive material contents and to provide protection of the content being shipped. These content containers are also referred to as product containers. Descriptions, illustrations, and the packaging limitation for these configurations are provided in the Addendum [See 5.e(2)] Sections 1.2.2.1.1, 1.2.2.1.2, and 1.2.2.1.3.

The 9977 is evaluated for shipment of radioactive contents in a specialized Engineered Container configuration, the Isentropic Compression Experiment (ICE) test apparatus, which consists of a stainless steel assembly containing approximately 8 gm of  $^{239}\text{Pu}$  or its dose equivalent, within the mass limits of the ICE Radioactive Contents [Table 1 in Reference 5.(e)(3)]. The ICE apparatus contains no plastics other than Viton<sup>®</sup> O-rings. The apparatus weighs less than 30 lb. The packing system, designed to protect the ICE apparatus from normal transport vibrations, consists of two (2) sets of Spring Mounts (6061-T6 aluminum), springs (ASTM A 288 QQW-470 steel music wire), and 2¼-inch square by 3½ inch long Foam Bumper Blocks (General Plastics Last-A-Foam<sup>®</sup>, TF-5070-10). The ICE assembly configuration positioned in the 6CV is shown in Figure 3.

The 9977 is evaluated for shipment of irradiated Advance Gas Reactor (AGR-1) Fuel Compacts shipped in the shielded container Small Gram Quantity (SGQ)-SC3. The AGR-1 Fuel Compact has less than 1 gram of radioactive material and contains no more than 1000 ppm total of  $^{251}\text{Cf}$ ,  $^{249}\text{Cf}$ ,  $^{242\text{m}}\text{Am}$ ,  $^{243}\text{Cm}$ ,  $^{245}\text{Cm}$ , and  $^{247}\text{Cm}$ . The AGR-1 Fuel Compact has less than 6 grams of total content mass (radioactive material plus impurities). The materials of the AGR-1 Fuel Compact are defined in Addendum 3, Appendix 1.2 [See 5.(e)(4)]. The AGR-1 Compact

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shall be placed in a pipe Container (consisting of a threaded pipe section closed with pipe caps) with a minimum closed length of 2.8 inches. The AGR-1 Fuel Compact in the pipe Container is then placed inside the SGQ-SC3 container. The SGQ-SC3 container provides gamma shielding and consists of tungsten shielding material encapsulated in a stainless steel container with threaded closure. The SGQ-SC3 container is able to withstand the worst case Hypothetical Accident Condition (HAC) drop without loss of its ability to shield its radioactive contents. The SGQ-SC3 permits transmission of any decay heat released by the radioactive contents. The SGQ-SC3 container is located axially within the 9977 6 inch Containment Vessel (6CV) by aluminum foam Spacers. The typical packaging configuration is shown in Figure 4. Addendum 3, Appendix 1.1 contains the drawings detailing the shielded container components [See 5.(e)(4)].

The 9977 is evaluated for shipment of Content Type 4 (i.e., Sources), which will assist with the Off Site Source Recovery Project for the disposition of radioactive sources. For Sources, various radioactive isotopes have been proposed for shipment, including  $^{238}\text{Pu}$ ,  $^{239}\text{Pu}$ ,  $^{241}\text{Am}$ ,  $^{244}\text{Cm}$ ,  $^{252}\text{Cf}$ ,  $^{90}\text{Sr}$ ,  $^{226}\text{Ra}$ ,  $^{137}\text{Cs}$ ,  $^{60}\text{Co}$ , and  $^{192}\text{Ir}$ , with the Special Actinide Isotopes ( $^{242\text{m}}\text{Am}$ ,  $^{243}\text{Cm}$ ,  $^{245}\text{Cm}$ ,  $^{247}\text{Cm}$ ,  $^{249}\text{Cf}$  and  $^{251}\text{Cf}$ ) limited to a total of 1,000 ppm. Three different types of Shielded Containers are used in transporting these Sources. The first, SGQ-SC1, is constructed of lead and encapsulated in stainless steel, with a threaded stainless steel closure. The lead provides gamma-radiation shielding. The second, SGQ-SC2, is constructed of high-density polyethylene (HDPE). The HDPE provides neutron radiation shielding. The third, SGQ-SC3, is constructed of tungsten and is also encapsulated in stainless steel, with a threaded stainless steel closure. An Engineered Container (SGQ-EC1) is also used for shipments of unshielded sources and pieces that do not require shielding, provided that the administrative dose rate limits of 180 mrem/hr (on contact of the unshielded source or piece) and 9 mrem/hr (at a distance of 1 meter of the unshielded source or piece) are met. Shielded sources and pieces must go in one of the appropriate approved shielded containers because the shielding integrity of the sources cannot be assured in HAC for the SGQ-EC1 container. The typical packaging configuration is shown in Figures 4, 5, 6, and 7. Addendum 3, Appendix 1.1 contains the drawings detailing the shielded container components [See 5.(e)(4)].

The 9977 is evaluated for the shipment of Training Sources between DOE sites and Laboratories in support of general programs. Training Sources contents may include radioactive isotopes ( $^{238}\text{Pu}$ ,  $^{239}\text{Pu}$ ,  $^{240}\text{Pu}$ ,  $^{241}\text{Pu}$ ,  $^{242}\text{Pu}$ ,  $^{241}\text{Am}$ ,  $^{243}\text{Am}$ ,  $^{252}\text{Cf}$ ,  $^{248}\text{Cm}$ ,  $^{237}\text{Np}$ ,  $^{232}\text{Th}$ ,  $^{234}\text{U}$ ,  $^{235}\text{U}$ ,  $^{236}\text{U}$ ,  $^{238}\text{U}$ ) with impurities (such as Be, Al, Mg, Na, F). The Training Sources contents shall have a decay heat of 3.5 W or less, and the contents will be placed in an engineered container, a convenience container with an attached top, or a Training Source Engineered Container.

The 9977 is evaluated for a content consisting of 3013 stabilized plutonium and uranium oxides shipped in a Dual 3013 configuration. The content/configuration request stems from the need to ship these materials, which reside at the Los Alamos National Laboratory (LANL) to the Purification Area Vault (PAV) at the Savannah River Site for storage pending final disposition. In addition to the NNSA program the contents will also support general disposition of other materials at various DOE sites. The package maximum allowable radioactive decay heat rate (thermal) limit is also increased to 38 watts, to accommodate two 3013s loaded to

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the DOE-STD-3013 limit. A Heat Dissipation Sleeve (HDS) made of 6061-T6 aluminum, surrounds the outside of the 6CV within the Drum Line cavity, and it is located between the Top and Bottom Load Distribution Fixtures. The HDS has been added to enhance heat transfer from the package because of the increased decay heat load of the Dual 3013 contents. The Dual 3013 configuration is shown in Figure 8.

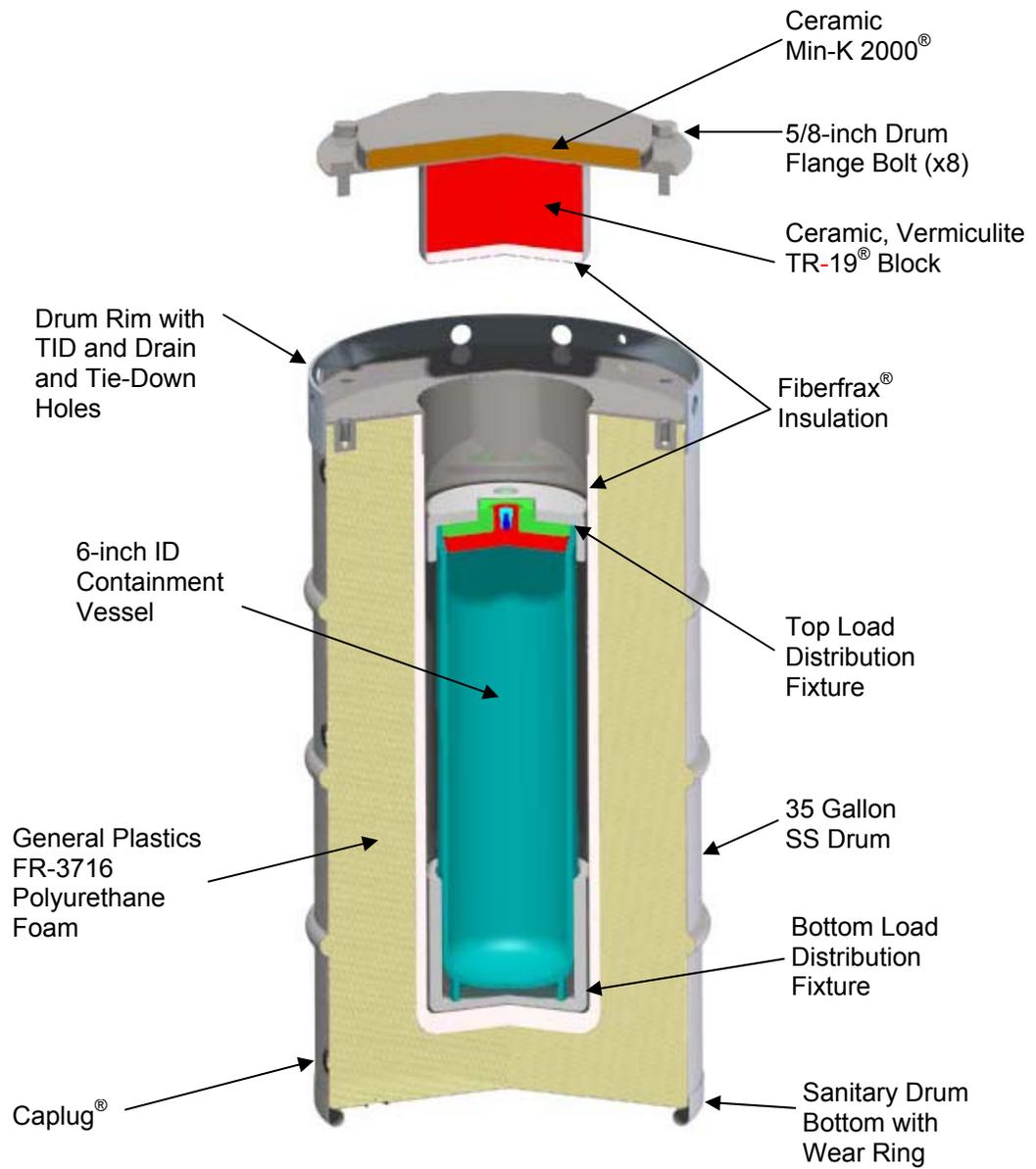
Neither 9977 materials nor component geometry provide significant radiation shielding. Dose-rate attenuation is provided primarily by the distance between the source and points external to the package.

The 9977 design does not incorporate materials specifically for the purpose of poisoning or moderating neutron radiation. Subcriticality is ensured by limiting the package fissile material mass.

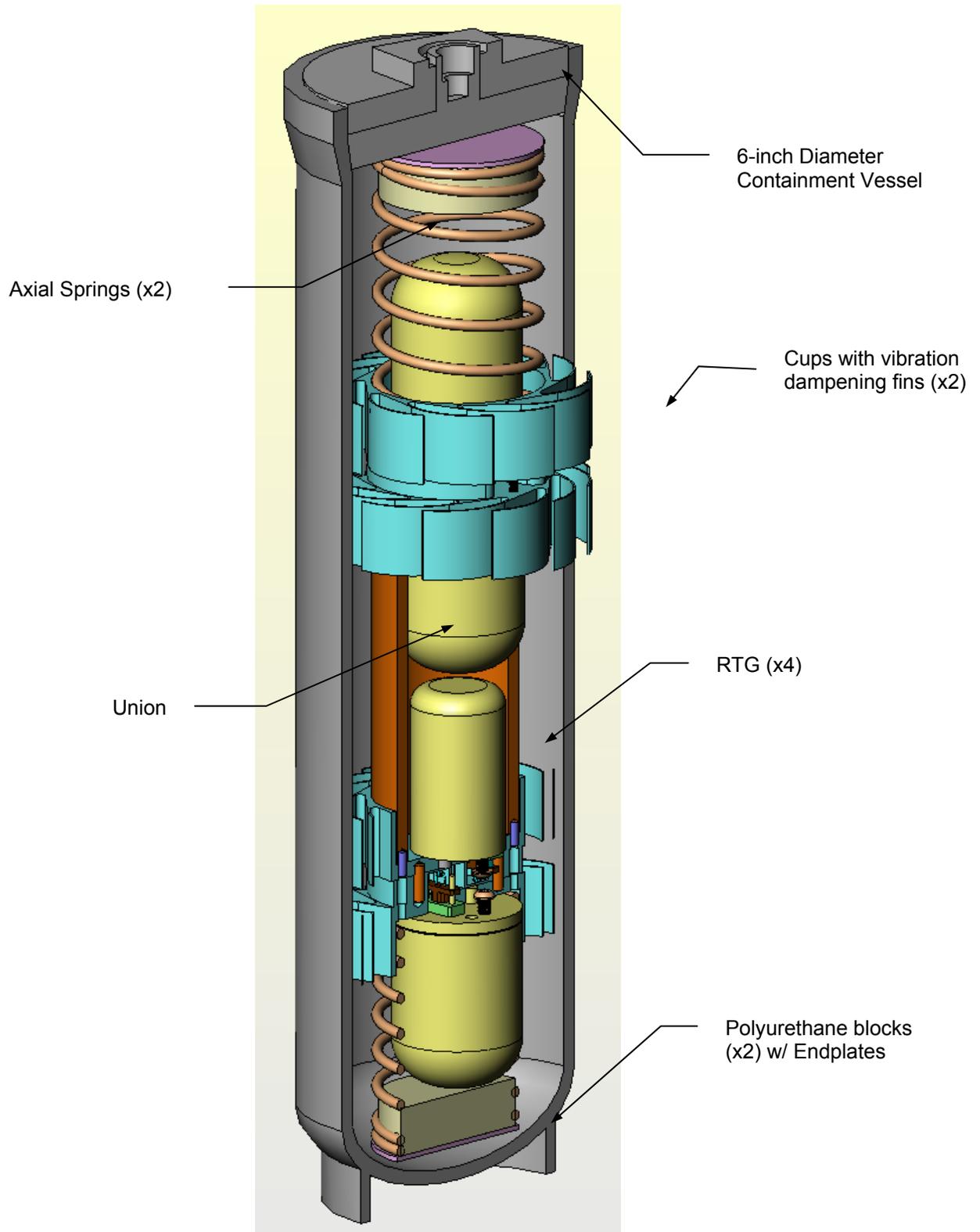
Option to use the radiofrequency identification (RFID) system: The option to use the RFID system is justified by Addendum [See 5(e)(5)] as being within the existing safety basis. The RFID Guide [See 5(e)(6)] provides instructions for installing the DOE ARG-US RFID tag to the 9977 package. The DOE ARG-US RFID tag is not considered a part of the package. The DOE ARG-US RFID tag is equipped with a suite of sensors-seal integrity, temperature, humidity, shock, radiation, and battery status. The seal sensor is a thin force-sensitive membrane switch that sits under one of the lid bolts of the drum cover when installed. The seal sensor may be credited as a Tamper-Indicating Device (TID) for enhanced security and safeguards, and the seal has been evaluated, and judged to be adequate, following the NRC Regulatory Guide 5.80 "Pressure Sensitive (PS) and Tamper-Indicating Device Seals for Material Control and Accounting (MC&A) of Special Nuclear Material," dated December 2010. The DOE ARG-US RFID tag may be used as TID seal [See 5(e)(14)] The DOE ARG-US RFID tag has a robust plastic front cover and the stainless-steel back plate that provide adequate protection of the tag internal components against damage under normal handling and transport. The tag weighs approximately 2.4 lb (with four Size-A Li-SOCl<sub>2</sub> batteries) and is approximately 8 inches wide x 7 inches high x 1.5 inches tall. Appendix B of the RFID Guide [See 5(e)(6)] provides documentation that the batteries used in the DOE ARG-US RFID tag are not subject to the hazardous material regulations and also contains the Material/Product Safety Data Sheet for the batteries.

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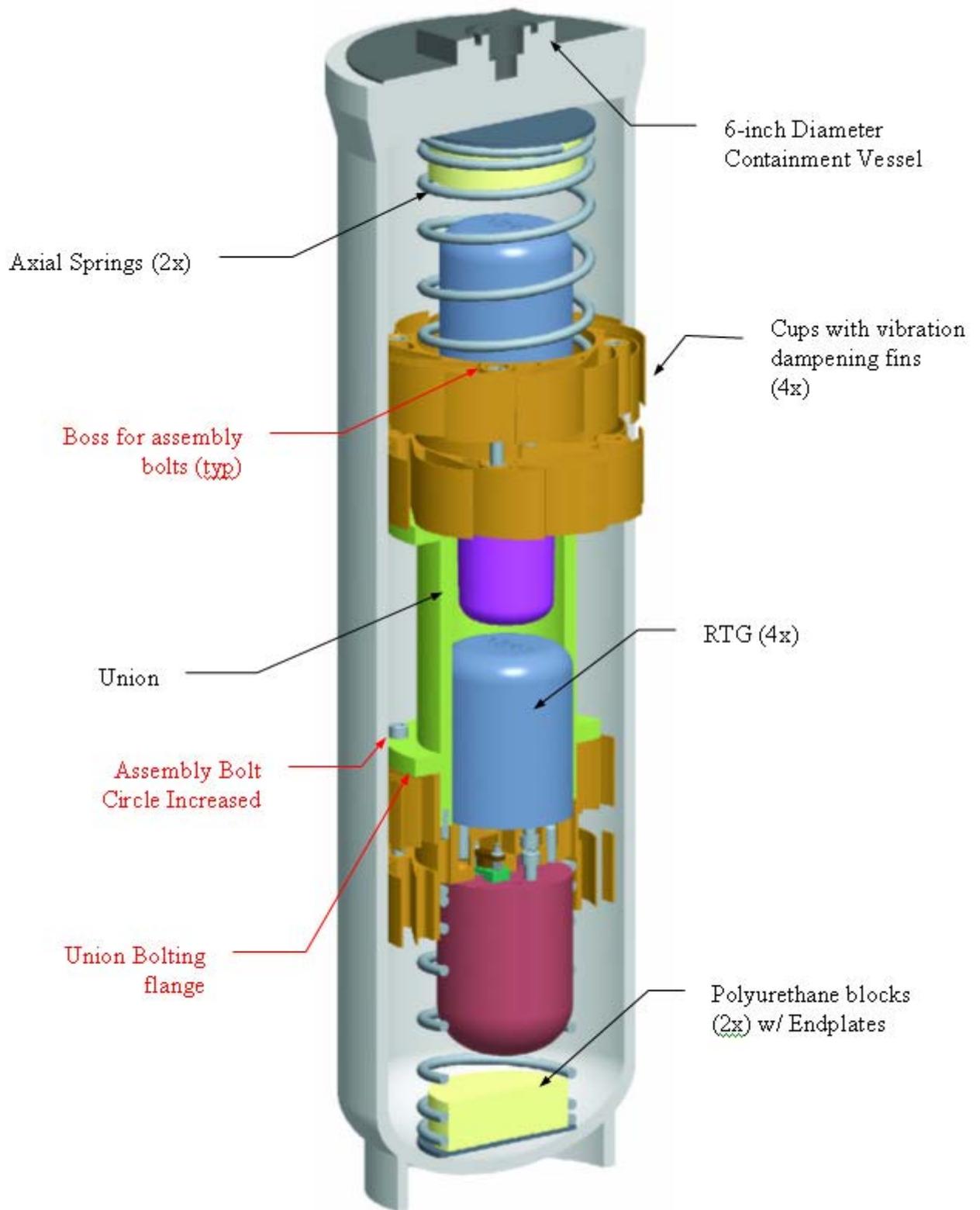
Option to install a DOE ARG-US RFID tag to a packaging to extend the periodic maintenance interval. For a package with an extension of the periodic maintenance interval, a specific DOE ARG-US RFID tag (with a unique serial number) is installed after a new CV seal is installed and tested. Since this specific RFID tag is assigned to monitor a specific 9977 package, the tag and package shall remain together for the entire maintenance period through the use of a label on the tag that records the RFID tag/package serial numbers, the date the RFID tag is attached, the maximum allowable ambient temperature, and the maintenance expiration date. During both use (loading, shipment, and unloading) and storage (loaded and empty) of the 9977 packaging, the CV must remain sealed over the entire approved extended maintenance interval. In the event that operations require the CV to be opened, then the old O rings shall be replaced with new O-rings, all the requirements for the extended maintenance interval shall be complied with for the new O-rings, and the sealing time shall be re-initialized to zero. If the ambient temperature limit is exceeded at any time, action shall be taken by placing a "Do Not Operate" tag on the package and segregating it from the working inventory. The conditions for the use of a 9977 packaging with an installed DOE ARG-US RFID tag to extend the period of maintenance interval are stated in 5(d)(10) of this CoC.



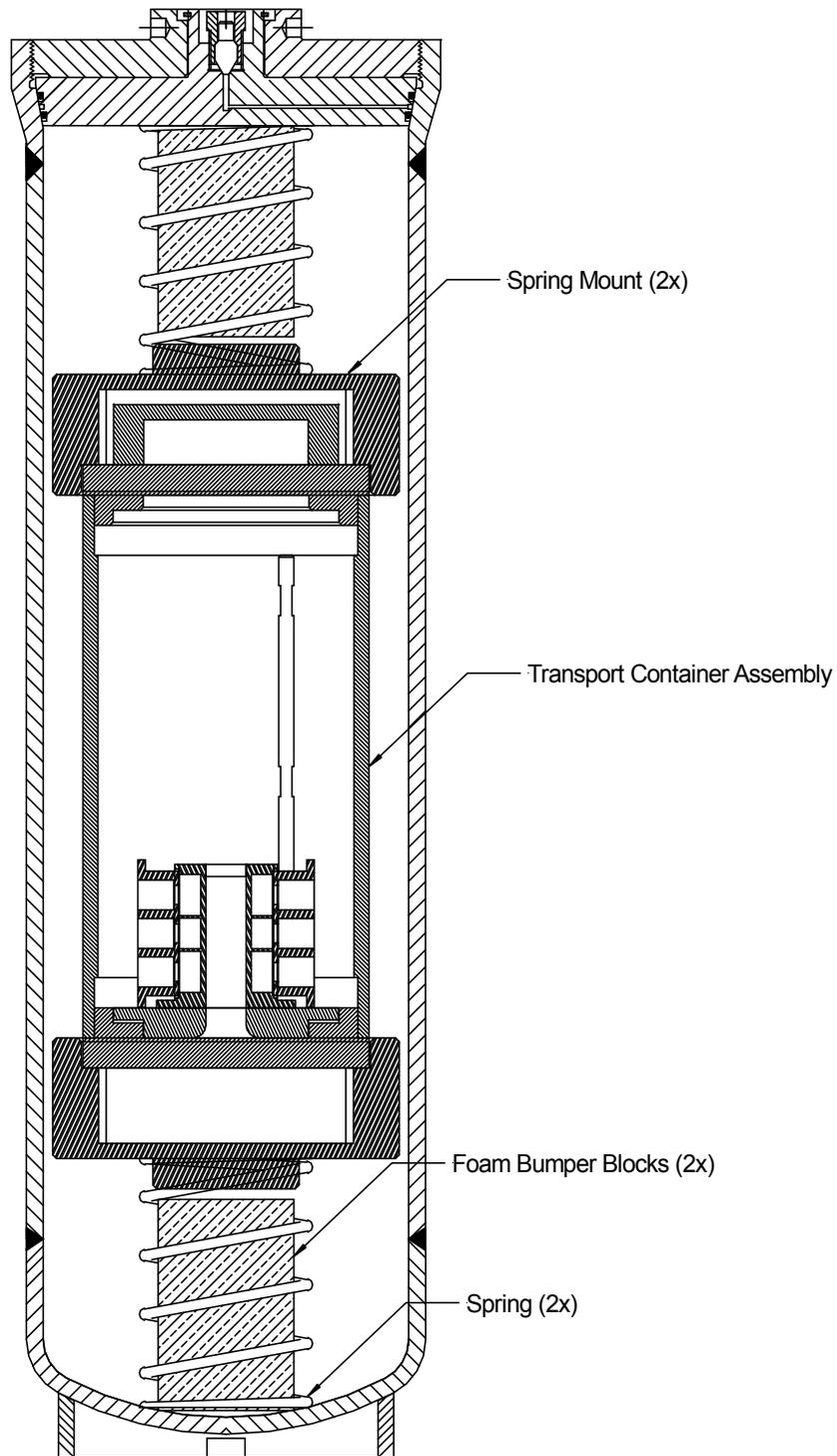
**Figure 1: Three-Dimensional Cut Away Illustration of the 9977**



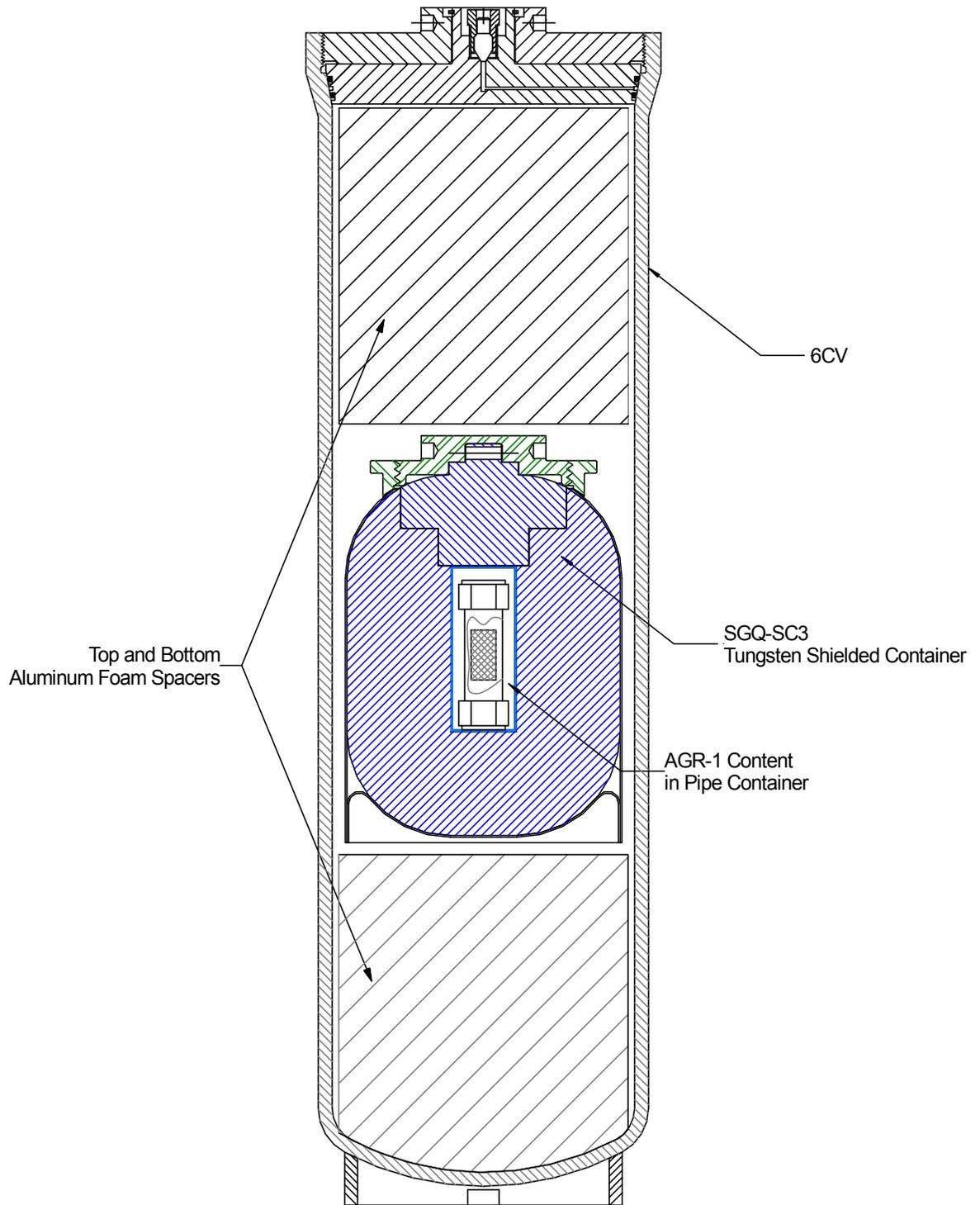
**Figure 2a: 6CV w/Radioisotope Thermoelectric Generator (RTG) Assembly**



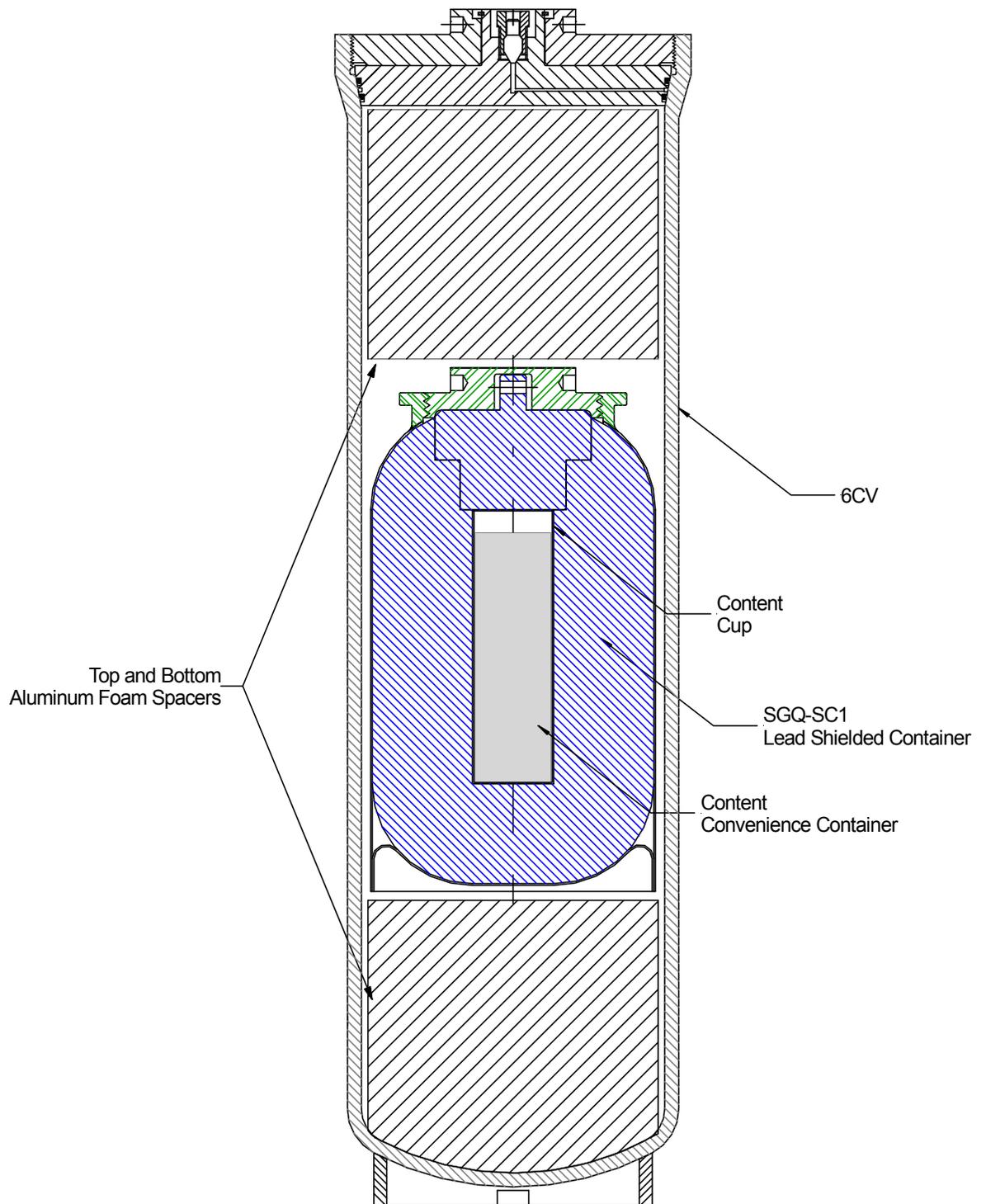
**Figure 2b: 6CV w/Alt. Radioisotope Thermoelectric Generator (RTG) Assembly**



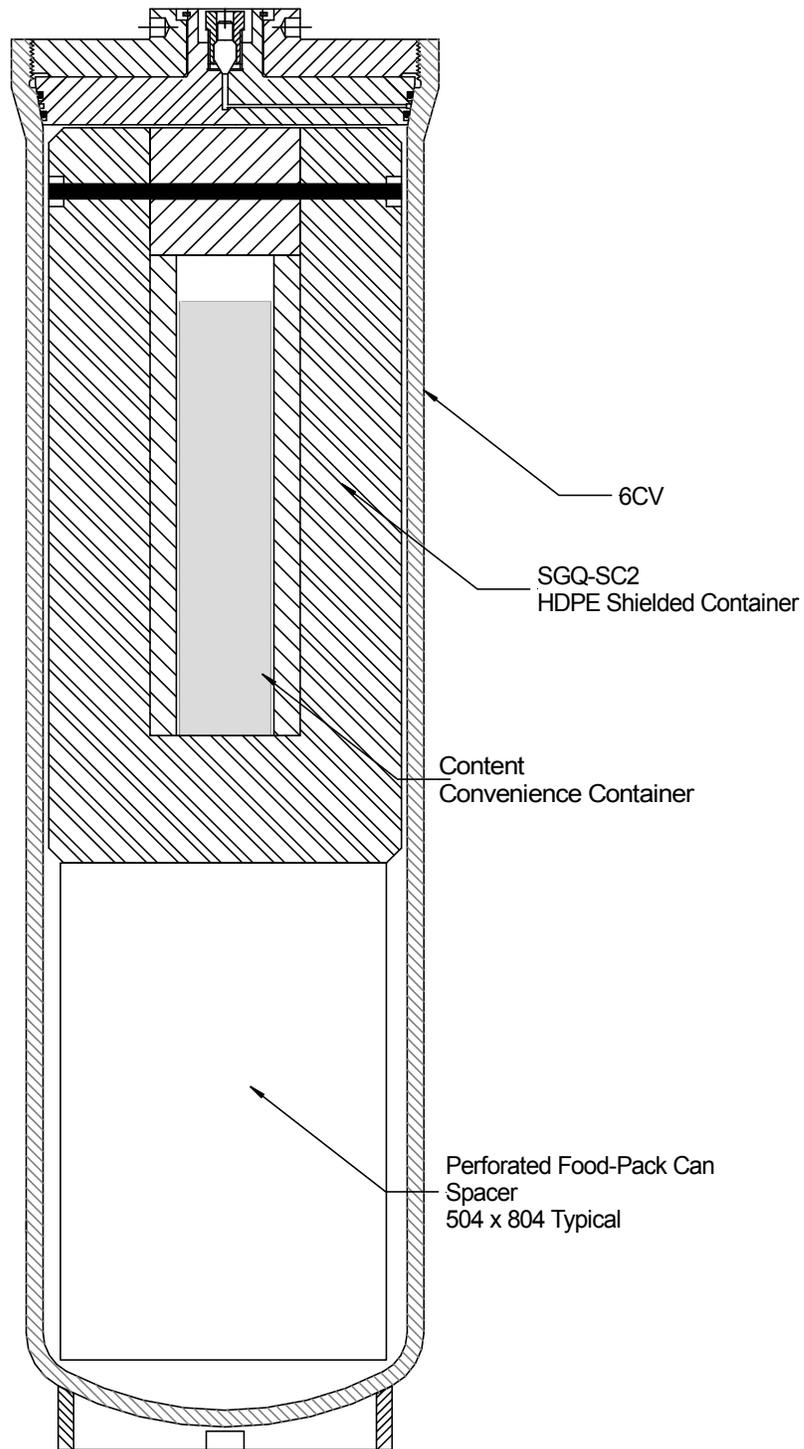
**Figure 3: 6CV w/ICE Apparatus Transport Container Assembly**



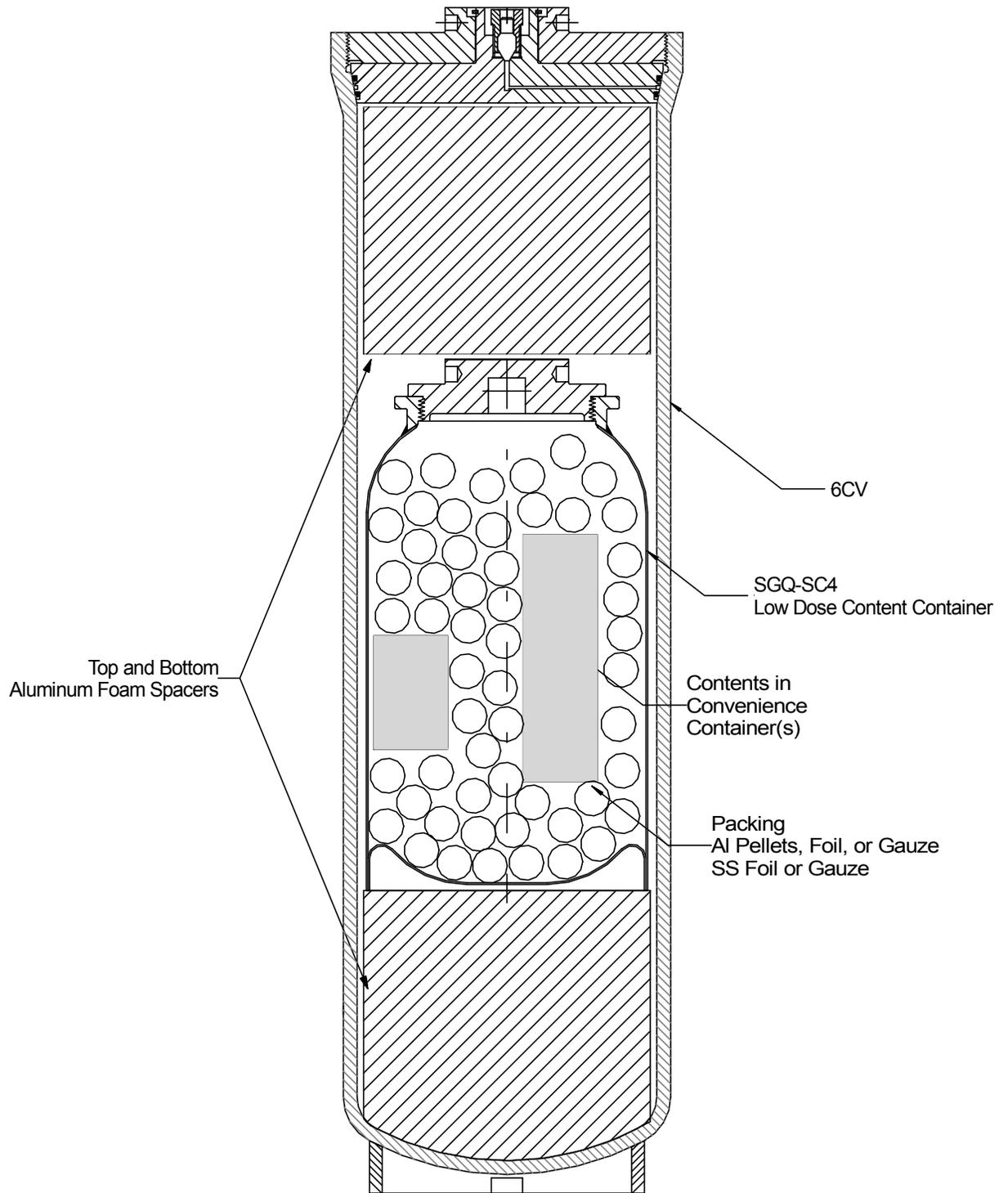
**Figure 4: SGQ-SC3 Configuration in 9977 (Tungsten Shielding)**



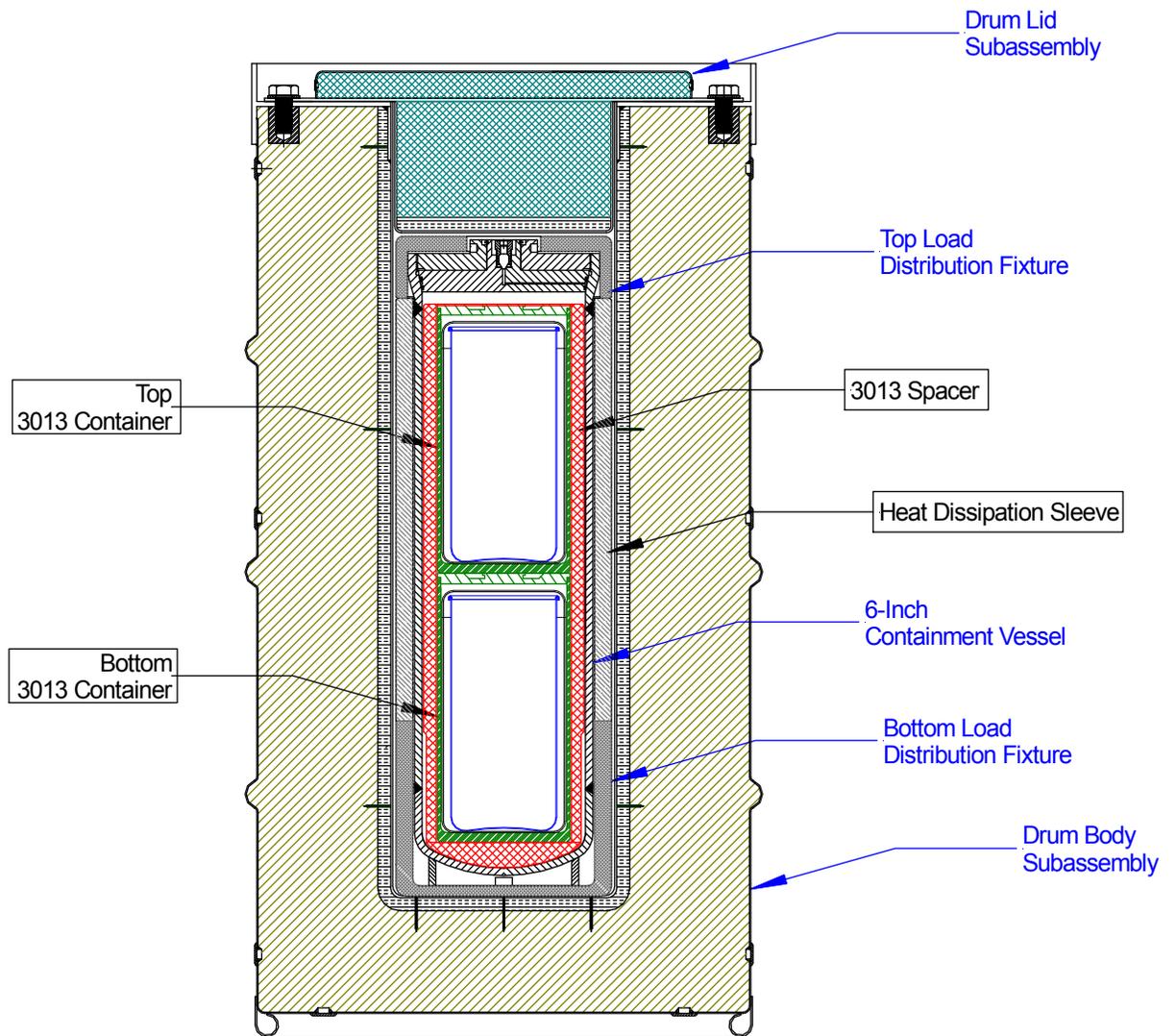
**Figure 5: SGQ-SC1 Configuration in 9977 (Lead Shielding)**



**Figure 6: SGQ-SC2 Configuration in 9977 (HDPE Shielding)**



**Figure 7: SGQ-EC1 Configuration in 9977 (Confinement)**



**Figure 8 Typical Dual-3013 Container Configuration in the 9977**

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(3) Drawings:

The packaging design is defined by the following Savannah River Site drawings:

R-R1-G-00020, Revision 2; 9977-Assembly with 6-inch Diameter Containment Vessel (U)

R-R2-G-00017, Revision 1; 9977-Drum and Liner Subassembly (U)

R-R2-G-00018, Revision 2; 9977- Drum Lid Subassembly (U)

R-R2-G-00019, Revision 1; 9977-Insulating Blanket Subassembly (U)

R-R2-G-00042, Revision 2; 9977-Six Inch Diameter Containment Vessel Subassembly (U)

R-R4-G-00032, Revision 3; 9977-Load Distribution Fixtures Details (U)

R-R4-G-00053, Revision 2; 9977-Sleeve and Plug Details (U)

Drawings for the ICE Container Assembly:

R83700, LANL Transport Container Assembly

1001-0269-0000, Platform, Pu Anode, Inner

1103-0355-0000, Panel, ICE, Floor

1103-0388-0000, Panel, 17mm Spacer, ICE

1103-0389-0000, Plug, Panel, 17mm Spacer

1350-2333-0000, Fitting, 1/8 to 1/8, Custom

1350-2357-0000, 90° Adaptor Fitting

1350-2495-0000, Probe Nut

1350-2496-0000, Mount, Probe Body, 3-Point

R83710, Transport Container Handle

R83711, Transport Container Anode Mount

R83712, Transport Canister Body

R83722, Transport Container Strain Relief

2-045, Viton O-Ring

502-440-716-AAA2, Socket Head Cap Screw, alloy steel

502-1420-1-AAA2, Socket Head Cap Screw, alloy steel

R-R1-G-00037, Revision 1, 9977 Small Gram Quantity-Shielded Container Type1 (U)

R-R1-G-00038, Revision 1, 9977 Small Gram Quantity-Shielded Container Type 2 (U)

R-R1-G-00039, Revision 1, 9977 Small Gram Quantity-Shielded Container Type 3 (U)

R-R1-G-00045, Revision 0, 9977 Small Gram Quantity-Engineered Container Type1 (U)

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R-R4-G-00073, Revision 1, 9977 Small Gram Quantity-Shielded Container Type 1 Spacers (U)

R-R4-G-00074, Revision 1, 9977 Small Gram Quantity-Shielded Container Type 3 Spacers (U)

R-R4-G-00081, Revision 0, 9977 3013 Spacer Details

(b) Contents

(1) Type and Form of Radioactive Material:

Package contents identified as Content Envelope C.1 and ICE are defined in Table 1 and packaging contents identified as Content Envelopes AC.1 through AC.5 are defined in Table 3. The materials of the AGR-1 Compact are defined in Addendum 3, Appendix 1.2 [See 5.(e)(4)]. Packaging contents identified as Type 4 contents are defined in Addendum 3, Table A.1.1 [See 5.(e)(4)]. The Training Sources are defined in Addendum 5, Table A.1.1 [See 5(e)(7)]. The contents are in solid form as metal pieces or oxides. In addition, when shipped in a Sealed Source configuration the Type 4 contents may include materials of several other chemical forms, including but not limited to, fluorides, chlorides, titanates, and sulfates. The Dual-3013 contents are defined in Table 7. The contents are in solid form as stabilized plutonium and uranium oxides.

Contents in liquid form are not permitted

(2) Maximum Quantity of Radioactive Material per Package:

- (a) Envelope C.1, Heat Sources and ICE. The total content mass listed in Table 1 excludes material containers and packing materials (i.e., RTG containers, springs, cups and union). Contents containers and content-specific configuration requirements are listed in Sections 1.2.2.1 and 1.2.2.2 of the SARP [See 5.(e)(1)].

Compatibility of the packaging materials of construction, packing materials, and the contents is discussed in Section 2.2.2 of the SARP [See 5.(e)(1)]. There are no material incompatibilities in the package. Since the 6CV is leaktight, it may become pressurized by heating of gases contained at the time of closure and pressurized further by gases generated from radioactive decay of the contents. The contents do not generate fission gases. The Maximum Normal Operating Pressure (MNOP) for the 6CV is 41.2 psig.

Except as stated in Table 1, small concentrations (<1000 ppm each) of other actinides, fission products, decay products, and neutron activation products are permitted. Assessment of these impurities may be based on process knowledge.

Except as stated in Table 1, inorganic material impurity quantities of less than 100 ppm each are permitted as long as the total mass is less than 0.1 weight percent of the total content mass. Assessment of these impurities may be based on process knowledge.

Content Envelope C.1 and ICE requirements are summarized in Table 2 by content envelope and container configuration.

Table 1- Contents

|                           | Material <sup>a, b</sup>       | C.1 Heat Sources weight% | C.1 Heat Sources grams | ICE Weight% | ICE grams <sup>e</sup> |
|---------------------------|--------------------------------|--------------------------|------------------------|-------------|------------------------|
| <b>Radioisotope</b>       | <sup>238</sup> Pu              | 100                      | 100                    | 0.04        | 0.03                   |
|                           | <sup>239</sup> Pu <sup>c</sup> | 40                       | 40                     | 100         | 8                      |
|                           | <sup>240</sup> Pu <sup>d</sup> | 13                       | 13                     | 6           | 2.2                    |
|                           | <sup>241</sup> Pu <sup>c</sup> | 1                        | 1                      | 0.2         | 0.005                  |
|                           | <sup>242</sup> Pu              | 1.5                      | 1.5                    | 0.06        | 8 <sup>f</sup>         |
|                           | <sup>241</sup> Am              |                          |                        | g           | 0.14                   |
|                           | <sup>232</sup> U <sup>c</sup>  | 1.4 × 10 <sup>-4</sup>   |                        |             |                        |
|                           | <sup>233</sup> U <sup>c</sup>  | 0.2                      |                        |             |                        |
|                           | <sup>234</sup> U               | 40                       |                        |             |                        |
|                           | <sup>235</sup> U <sup>c</sup>  | 40                       |                        |             |                        |
|                           | <sup>236</sup> U               | 16                       |                        |             |                        |
|                           | <sup>238</sup> U               | 40                       |                        |             |                        |
| <b>Impurities (grams)</b> | Ca                             | 15                       |                        |             |                        |
|                           | Fe                             | 5                        |                        |             |                        |
|                           | Cr                             | 2                        |                        |             |                        |
| <b>Total Mass (kg)</b>    | Radioactive Materials          | 0.1                      | 100                    |             | 8                      |
|                           | Impurities                     | 0.02                     | 20                     |             |                        |
|                           | All Contents                   | 0.1                      | 100                    |             | 8                      |

Notes

- a All contents shall be dry.
- b Pu/U content bulk density shall be no greater than 19.84 g/cc and no less than 2.0 g/cc.
- c Nuclide classified as "fissile" per DOE Good Practices Guide, Criticality Safety Good Practices Program, Guide For DOE Nonreactor Nuclear Facilities, DOE G 421.1-1, 3.79 Fissile Nuclide, 8-25-99.
- d <sup>240</sup>Pu shall be greater than <sup>241</sup>Pu.
- e Mass limit based on 8-gram <sup>239</sup>Pu dose equivalence.
- f The <sup>239</sup>Pu dose equivalent mass is 125 grams; the content Total Mass limit takes precedence.
- g <sup>241</sup>Am exists at the 9977 SARP Rev.2 impurity limit of 100 ppm.

Table 2- Summary of Requirements by Content and Configuration

| Content Envelope | Container Configuration                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                        |                                                                                                |
|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
|                  | Food-Pack Can                                                                                                                                                                                                                                                                                                                                                                                                | SNL RTGs                                                                                               | ICE Assembly                                                                                   |
| C.1              | maximum 100 g plastic (low-density polyethylene, nylon, and/or polyvinyl chloride tape)                                                                                                                                                                                                                                                                                                                      | manufactured per drawings listed<br>packing configuration control<br>maximum 100 grams<br>polyurethane |                                                                                                |
| ICE              |                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                        | maximum 8 g radioactive materials<br>maximum 100 g plastic<br>manufactured per drawings listed |
| All              | 19 watts maximum radioactive decay heat rate<br>less than 1000 ppm other radionuclides (unless otherwise stated in Table 1.2)<br>less than 100 ppm other inorganic impurities with total mass less than 0.1 weight percent (unless otherwise stated in Table 1.2)<br>100 lb maximum content weight (radioactive contents, convenience cans, contamination control devices, packing materials, spacers, etc.) |                                                                                                        |                                                                                                |

- (b) Envelope AC.1, Neptunium Metal. Section 1.2.2.2.1 of the Addendum [See 5.e(2)] provides figures and drawing numbers of Neptunium Metal Spheres and Storage Containers.

The two possible neptunium content configurations are shown in Figure A.1.2. of the Addendum [See 5.e(2)]. One configuration for this content envelope is the Neptunium Sphere which is a solid sphere of neptunium metal with cladding and shielding around the sphere, aluminum foil as dunnage, and a Vollrath convenience can. Additionally, this content may incorporate a configuration within the convenience can where an aluminum Storage Container is placed around the neptunium sphere assembly. The masses of the tungsten shielding shell and the two (2) nickel cladding shells are added to the mass of neptunium for a total assembly mass of 8026.9 grams.

The mass of the aluminum Storage Container is estimated at 3100 grams. Assuming that the density of crushed aluminum foil is about ½ that of a cast billet, the mass of aluminum foil inside the Vollrath can is estimated to be 790 grams. Additional aluminum foil will serve as dunnage outside the Vollrath Can, but its mass depends on the size of the empty dunnage can. Assuming the shipper selects a standard 404 x 700 food-pack can (4.25 inches diameter by 7 inches tall); the estimated mass of additional aluminum foil needed to fill the axial space above and/or below is 540 grams. The estimated maximum mass of aluminum, including fixture and foil, is 4430 grams. The mass of the alternative packaging configuration (aluminum foil dunnage only without the handling convenience fixture) will be less.

The Vollrath 88020 can serves as a handling convenience. The stainless steel can will be sealed by a wrapping of tape where the lid rests on the can body. The loaded Vollrath Can will be placed into the 6CV in the Sleeve and Plug configuration. The remaining space above the Vollrath Can may be packed with an empty food pack can and/or aluminum foil as final dunnage.

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Neptunium metal pieces to a maximum mass of 188 grams may be shipped under this content envelope. These pieces must be packaged in Food-Pack Cans or Engineered Containers.

- (c) Envelope AC.2, BeRP Ball. Section 1.2.2.2.2 of the Addendum [See 5.e(2)] provides figures and drawing numbers of Plutonium Ball and heat-sink fixture drawing.

The BeRP Ball is a Beryllium Reflected Plutonium Ball that contains 4484 grams of alpha-phase plutonium. Radioactive decay heat from the plutonium sphere is 10.656 watts which is much less than the package limit of 19 watts. Added to the mass of plutonium is the mass of the stainless steel shell for a total assembly mass of 4.5 kg. Table 4 presents configuration requirements for the Plutonium Ball content.

The mass of the aluminum heat-sink fixture is estimated conservatively at 3100 grams. Conservatively assuming that the density of crushed aluminum foil is about half that of a cast billet, the mass of aluminum foil inside the Vollrath Can is estimated to be 790 grams. Additional aluminum foil will serve as dunnage outside the Vollrath Can, but its mass depends on the size of the empty dunnage can. Assuming the shipper selects a standard 404 x 700 food-pack can (4.25 inches diameter by 7 inches tall) as dunnage, the estimated mass of additional aluminum foil needed to fill the axial space above and/or below the food-pack can is 540 grams. The estimated maximum mass of aluminum, including fixture and foil, is 4500 grams.

The Vollrath 88020 is a slip lid convenience can. The stainless steel can will be sealed by a wrapping of tape where the lid rests on the can body. The loaded Vollrath Can will be placed into the 6CV, followed by one empty and perforated food-pack or empty and unsealed slip-lid can to serve as dunnage. The space between the Vollrath Can and the dunnage can and between the dunnage can and the top of the vessel will be packed with aluminum foil as final dunnage.

- (d) Envelopes AC.3 and AC.4, Pu/U Metals. Section 1.2.2.2.3 of the Addendum [See 5.e(2)] provides figures and more details for these content envelopes.

Content Envelopes AC.3 and AC.4 must be loaded into the containment vessel with the incorporation of an aluminum Sleeve and Plug. The (one-piece) aluminum Sleeve and Plug component reduces the volume of the containment vessel in order to meet the Single Package Flooded condition requirement for sub-criticality found in 10 CFR 71.55, General Requirements for Fissile Material Packages. For array analyses, the aluminum Sleeve and Plug also provides spacing in order to meet the requirement for sub-criticality. The aluminum Sleeve and Plug also provides spacing in order to meet the requirement NCT Dose limit requirements.

These contents are packaged in 3013 containers, Food-Pack cans, or Engineered Containers and the product container is loaded into the containment vessel after the Sleeve and Plug has been installed. The general requirements for all packages as documented in Addendum Section 1.2.2 apply to these contents.

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For Content Envelope AC.3, if the radionuclide content mass is equal to or greater than 3 kg per innermost material container, the following restrictions apply:

- The sum of the radial wall thicknesses of all nested cans shall not exceed 0.26 inch.
- The sum of the thicknesses of the tops and bottoms of all nested cans shall not exceed 1.77 inches.
- The innermost material container shall be at least 4 inches in diameter and at least 4 inches long (i.e., minimum can size 400 x 400).

For Content Envelope AC.4 material with a mass less than or equal to 450 grams, the requirement to use of the aluminum Sleeve and Plug does not apply. Contents meeting these conditions and packaged in 3013 containers, Food-Pack cans, or an Engineered Container are permitted to be loaded into the containment vessel with no additional packaging requirements. Aluminum foil may be placed around the product container as dunnage to restrict movement within the containment vessel.

- (e) Envelope AC.5, U Metal. Section 1.2.2.2.4 of the Addendum [See 5.e(2)] provides figures and more details for this content envelope.

Content Envelope AC.5 maximizes the Highly Enriched uranium metal, alloyed with up to 10% molybdenum, which may be shipped in the 9977. This content must be packaged in a 3013 container, a Food-Pack can, or an Engineered Container. The convenience container must be placed within a (one-piece) aluminum Sleeve and Plug component followed by an empty, perforated food-pack can, followed by aluminum foil dunnage. Aluminum foil may be placed around the product container as dunnage to restrict movement within the containment vessel. Requirements applicable to all packages as documented in Addendum [See 5.5(2)] Section 1.2.2 apply to this content envelope.

The Content Envelope AC.5 separate mass limit is dependent upon its percent enrichment. Contents with less than 95% <sup>235</sup>U have a mass limit of 18 kg. Content with enrichment greater than 95% (to a maximum of 100 %) <sup>235</sup>U have a mass limit of 16 kg. For Content Envelope AC.5, if the radionuclide content mass is equal to or greater than 3 kg per innermost material container, the following restrictions apply:

- The sum of the radial wall thicknesses of all nested cans shall not exceed 0.26 inch.
- The sum of the thicknesses of the tops and bottoms of all nested cans shall not exceed 1.77 inches.
- The innermost material container shall be at least 4 inches in diameter and at least 4 inches long (i.e. minimum can size 400 x 400).

**Table 3 - Content Envelopes**

|                                                                      | Material <sup>a,b</sup>               | AC.1<br>Neptunium<br>Metal | AC.2<br>BeRP Ball<br>Metal | AC.3 <sup>c</sup><br>Pu/U<br>Metal | AC.4 <sup>c</sup><br>Pu/U<br>Metal | AC.5 <sup>c</sup><br>U<br>Metal |
|----------------------------------------------------------------------|---------------------------------------|----------------------------|----------------------------|------------------------------------|------------------------------------|---------------------------------|
| <b>Radioisotope</b><br>(Weight Percent of Radioactive Material Mass) | <sup>238</sup> Pu                     | 1.6 × 10 <sup>-3</sup>     | 0.02                       | 2                                  | 2                                  |                                 |
|                                                                      | <sup>239</sup> Pu <sup>d</sup>        | 3.2 × 10 <sup>-2</sup>     | 93.74                      | 100                                | 100                                |                                 |
|                                                                      | <sup>240</sup> Pu <sup>e</sup>        | 2.3 × 10 <sup>-3</sup>     | 5.94                       | 25                                 | 50                                 |                                 |
|                                                                      | <sup>241</sup> Pu <sup>d</sup>        | 6.2 × 10 <sup>-5</sup>     | 0.272                      | 15                                 | 15                                 |                                 |
|                                                                      | <sup>242</sup> Pu                     | 3.2 × 10 <sup>-4</sup>     | 0.028                      | 5                                  | 5                                  |                                 |
|                                                                      | <sup>241</sup> Am + <sup>241</sup> Pu | 7.2 × 10 <sup>-4</sup>     | 0.272                      | 15                                 | 15                                 |                                 |
|                                                                      | <sup>243</sup> Am                     | 0.18                       |                            |                                    |                                    |                                 |
|                                                                      | <sup>237</sup> Np                     | 98.8 <sup>f</sup>          |                            |                                    |                                    |                                 |
|                                                                      | <sup>232</sup> U <sup>d</sup>         |                            |                            | 1 × 10 <sup>-7</sup>               | 1 × 10 <sup>-7</sup>               | 1 × 10 <sup>-7</sup>            |
|                                                                      | <sup>233</sup> U <sup>d</sup>         | 3.5 × 10 <sup>-3</sup>     |                            | 0.5                                | 0.5                                | 0.5                             |
|                                                                      | <sup>234</sup> U                      | 5.7 × 10 <sup>-4</sup>     |                            | 100                                | 100                                | 100                             |
|                                                                      | <sup>235</sup> U <sup>d</sup>         | 2.8 × 10 <sup>-2</sup>     |                            | 100                                | 100                                | 100/95 <sup>g</sup>             |
|                                                                      | <sup>236</sup> U                      | 1.6 × 10 <sup>-4</sup>     |                            | 40                                 | 40                                 | 40                              |
|                                                                      | <sup>238</sup> U                      | 3.1 × 10 <sup>-3</sup>     |                            | 100                                | 100                                | 100                             |
| <b>Impurities <sup>h</sup></b><br>(%)                                | Al, B, F, Li, Mg, Na                  |                            |                            |                                    |                                    |                                 |
|                                                                      | Be                                    |                            |                            |                                    |                                    |                                 |
|                                                                      | Mo                                    |                            |                            |                                    |                                    | 10                              |
|                                                                      | C                                     |                            |                            |                                    |                                    |                                 |
| <b>Total Mass</b><br>(kilograms)                                     | Radioactive<br>Materials              | 0.188/6.07 <sup>i</sup>    | 4.48                       | 4.4                                | 0.45/2 <sup>j</sup>                | 16/18 <sup>g</sup>              |
|                                                                      | Impurities                            |                            | 0.0215                     | 3.08 <sup>k</sup>                  |                                    |                                 |
|                                                                      | All Contents                          | 0.188/6.07 <sup>i</sup>    | 4.5                        | 4.4                                | 0.45/2 <sup>j</sup>                | 16/18 <sup>g</sup>              |

- All contents shall be dry.
- Pu/U content bulk density shall be no greater than 19.84 g/cc and no less than 2.0 g/cc.
- Contents shall be stabilized in accordance with DOE-STD-3013, Section 6.1.1.
- Nuclide classified as "fissile" per DOE Good Practices Guide, Criticality Safety Good Practices Program, Guide For DOE Nonreactor Nuclear Facilities, DOE G 421.1-1, 3.79 Fissile Nuclide, 8-25-99
- <sup>240</sup>Pu shall be greater than <sup>241</sup>Pu
- 100-year accumulation of daughter products incorporated into thermal and nuclear safety evaluations.
- The content mass limit is based on the percentage of <sup>235</sup>U. 16 kg of Content with up to 100 wt% <sup>235</sup>U are allowed. 18 kg of Content with up to 95 wt% <sup>235</sup>U are allowed.
- Less than 0.005 grams of (α, n) impurities {aluminum, beryllium, boron, fluorine, lithium, magnesium, and sodium} are permitted.
- The mass limit is based on the content configuration. 6.07 kg is allowed as the Np Sphere configuration. 188 grams is allowed if the content consists of pieces.
- The mass limit is based on the content packing configuration. 2 kg of Content in the Sleeve and Plug configuration is allowed. 450 grams of Content placed directly into the 6CV is allowed.
- The impurity limit is based on the DOE-STD-3013 requirement that plutonium plus uranium mass shall not be less than 30 weight percent of the total content mass

**Table 4 - Summary of Packaging Configuration Requirements**

| Content Envelope                                  | Configuration                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                  |
|---------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                   | Food-Pack Cans or Engineered Containers                                                                                                                                                                                                                                                                                                                                                                  | 3013                                                                                                                                                                                                                                                                                                                             |
| AC.1<br>Neptunium Metal<br>Sphere<br>Or<br>Pieces | <ul style="list-style-type: none"> <li>aluminum Sleeve and Plug required</li> <li>maximum content 188 grams if pieces</li> <li>maximum 100 grams plastic</li> <li>maximum 2000 grams stainless steel cans (Vollrath)</li> <li>maximum 4500 grams aluminum (heat-sink fixture and/or foil)</li> </ul>                                                                                                     | NA                                                                                                                                                                                                                                                                                                                               |
| AC.2<br>BeRP<br>Ball                              | <ul style="list-style-type: none"> <li>maximum 100 grams plastic</li> <li>maximum 2000 grams stainless steel cans (Vollrath)</li> <li>maximum 4500 grams aluminum (heat-sink fixture and/or foil)</li> </ul>                                                                                                                                                                                             | NA                                                                                                                                                                                                                                                                                                                               |
| AC.3<br>Pu Metal                                  | <ul style="list-style-type: none"> <li>aluminum Sleeve and Plug required</li> <li>maximum 100 grams plastic</li> <li>if <math>\geq 3</math>kg per food-pack can <ul style="list-style-type: none"> <li>* sum of can walls &lt; 0.26 inches</li> <li>* sum of can tops &amp; bottoms &lt; 1.77 inches</li> <li>* 400 x 400 can or bigger</li> </ul> </li> </ul>                                           | <ul style="list-style-type: none"> <li>aluminum Sleeve and Plug required</li> <li>if <math>\geq 3</math>kg per inner/material can <ul style="list-style-type: none"> <li>* sum of can walls &lt; 0.26 inches</li> <li>* sum of can tops &amp; bottoms &lt; 1.77 inches</li> <li>* 400 x 400 can or bigger</li> </ul> </li> </ul> |
| AC.4<br>Pu Metal                                  | <ul style="list-style-type: none"> <li>aluminum Sleeve and Plug required (unless total radioactive contents mass is less than 450 grams)</li> <li>maximum 100 grams plastic</li> </ul>                                                                                                                                                                                                                   | <ul style="list-style-type: none"> <li>aluminum Sleeve and Plug required (unless total radioactive contents mass is less than 450 grams)</li> </ul>                                                                                                                                                                              |
| AC.5<br>U Metal                                   | <ul style="list-style-type: none"> <li>aluminum Sleeve and Plug required</li> <li>maximum 100 grams plastic</li> <li>if <math>\geq 3</math>kg per food-pack can <ul style="list-style-type: none"> <li>* sum of can walls &lt; 0.26 inches</li> <li>* sum of can tops &amp; bottoms &lt; 1.77 inches</li> <li>* 400 x 400 can or bigger</li> </ul> </li> </ul>                                           | <ul style="list-style-type: none"> <li>aluminum Sleeve and Plug required</li> <li>if <math>\geq 3</math>kg per inner/material can <ul style="list-style-type: none"> <li>* sum of can walls &lt; 0.26 inches</li> <li>* sum of can tops &amp; bottoms &lt; 1.77 inches</li> <li>* 400 x 400 can or bigger</li> </ul> </li> </ul> |
| All                                               | <ul style="list-style-type: none"> <li>19 watts maximum radioactive decay heat rate</li> <li>less than 1000 ppm other radionuclides (unless otherwise stated)</li> <li>less than 100 ppm other inorganic impurities with total mass less than 0.1 weight percent (unless otherwise stated)</li> <li>100 lb maximum content weight (radioactive contents, product cans, Sleeve and Plug, etc.)</li> </ul> |                                                                                                                                                                                                                                                                                                                                  |

Note: Can wall thickness limits are driven by criticality concerns and do not apply to the Neptunium Metal Sphere or Parts

- (f) The AGR-1 Fuel Compact has less than 1 gram of radioactive material and contain no more than 1000 ppm total of  $^{251}\text{Cf}$ ,  $^{249}\text{Cf}$ ,  $^{242\text{m}}\text{Am}$ ,  $^{243}\text{Cm}$ ,  $^{245}\text{Cm}$ , and  $^{247}\text{Cm}$ . The AGR-1 Fuel Compact has less than 6 grams of total content mass (radioactive material plus impurities). The materials of the AGR-1 Compact are defined in Addendum 3, Appendix 1.2 [See 5.(e)(4)].

The AGR-1 Fuel Compact shall be placed in a pipe Container (consisting of a threaded pipe section closed with pipe caps) with a minimum closed length of 2.8 inches. The AGR-1 Fuel Compact in the pipe Container is then placed inside the SCQ-SC3 container. The SGQ-SC3 container provides gamma shielding and consists of tungsten shielding material encapsulated in a stainless steel container with threaded closure. The SGQ-SC3 container is located axially within the 9977 6 inch Containment Vessel (6CV) by aluminum foam Spacers. The typical packaging configuration is shown in Figure 4. Addendum 3, Appendix 1.1 contains the drawings detailing the shielded container components [See 5.(e)(4)].

The maximum allowable radioactive decay heat rate is 19 watts.

- (g) For the Type 4 content (i.e., Sources) various radioactive isotopes have been proposed for shipment, including  $^{238}\text{Pu}$ ,  $^{239}\text{Pu}$ ,  $^{241}\text{Am}$ ,  $^{244}\text{Cm}$ ,  $^{252}\text{Cf}$ ,  $^{90}\text{Sr}$ ,  $^{226}\text{Ra}$ ,  $^{137}\text{Cs}$ ,  $^{60}\text{Co}$ , and  $^{192}\text{Ir}$ , with the Special Actinide Isotopes ( $^{242\text{m}}\text{Am}$ ,  $^{243}\text{Cm}$ ,  $^{245}\text{Cm}$ ,  $^{247}\text{Cm}$ ,  $^{249}\text{Cf}$  and  $^{251}\text{Cf}$ ) limited to a total of 1,000 ppm. The content limits for Type 4 contents are shown in Table 5 below and in Addendum 3, Tables A.1.1 *Small Gram Contents* [See 5.(e)(4)]. A summary of the requirements by content and configuration is shown in Table A.1.2 of Addendum 3 and Appendix 1.2 of Addendum 3 contains the drawing details for the three shielded containers, engineered container, and container components [See 5.(e)(4)].

Table 5: Type 4 (Sources) Contents

| Isotope    | Maximum Mass Limit<br>[g] | Maximum Activity<br>[Ci] |
|------------|---------------------------|--------------------------|
| Co-60      | 1.0E-04                   | 0.11                     |
| Cs-137     | 1.0E-01                   | 8.70                     |
| Ir-192     | 3.8E-03                   | 35.00                    |
| Sr-90/Y-90 | 1.0E+00                   | 281.80                   |
| Ra-226     | 2.0E-01                   | 0.20                     |
| Am-241     | 1.0E+00                   | 3.43                     |
| Cf-252     | 6.7E-06                   | 0.0036                   |
| Cm-244     | 1.0E+00                   | 80.90                    |
| Pu-238     | 2.0E-01                   | 3.42                     |
| Pu-239     | 6.6E+01                   | 4.09                     |

Gamma-sources will be placed in the lead-shielded containers (SGQ-SC1), which will then, in turn, be placed into the 6CV in accordance with the allowable content configuration, defined in Table A.1.2 of Addendum 3 [See 5.(e)(4)]. Gamma-sources can also be placed in the tungsten-shielded containers (SGQ-SC3), as the tungsten-shielded containers are an acceptable substitute for the lead-shielded containers. The decay heat load for the SGQ-SC1 and SGQ-SC3 containers are limited to 6 watts and 19 watts, respectively.

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The neutron-sources will be placed in the HDPE shielded container (SGQ-SC2), which will then, in turn, be placed into the 6CV in accordance with the allowable content configuration, defined in Table A.1.2 of Addendum 3 [See 5.(e)(4)]. The decay heat load for the SGQ-SC2 container is limited to 3 watts.

An Engineered Container (SGQ-EC1) can be used for shipments of unshielded sources and pieces that do not require shielding, provided that the administrative dose rate limits of 180 mrem/hr (on contact of the unshielded source or piece) and 9 mrem/hr (at a distance of 1 meter of the unshielded source or piece) are met following the procedures in section 7.1.1.2 of Addendum 3 [See 5.(e)(4)]. Shielded sources and pieces must go in one of the appropriated approved shielded containers because the shielding integrity of the sources cannot be assured in HAC for the SGQ-EC1 container. The unshielded source(s) and pieces not requiring shielding are placed in the SGQ-EC1 container, which will then, in turn, be placed into the 6CV in accordance with the allowable content configuration, defined in Table A.1.2 of Addendum 3 [See 5.(e)(4)]. The decay heat load for the SGQ-EC1 is 19 watts.

- (h) The Training Sources contents may include radioactive isotopes ( $^{238}\text{Pu}$ ,  $^{239}\text{Pu}$ ,  $^{240}\text{Pu}$ ,  $^{241}\text{Pu}$ ,  $^{242}\text{Pu}$ ,  $^{241}\text{Am}$ ,  $^{243}\text{Am}$ ,  $^{252}\text{Cf}$ ,  $^{248}\text{Cm}$ ,  $^{237}\text{Np}$ ,  $^{232}\text{Th}$ ,  $^{234}\text{U}$ ,  $^{235}\text{U}$ ,  $^{236}\text{U}$ ,  $^{238}\text{U}$ ) with impurities (such as Be, Al, Mg, Na, F). The maximum masses for the Training Sources contents are limited to masses noted in Table 6. The packaging configuration requirements specified in Table A.1.2 of Addendum 5 [See 5.(e)(7)], *Summary of Requirements*, must be followed. The packaging configuration requirements specified in Addendum 5 Section 1.2.2 [See 5.(e)(7)] must be followed.

**Table 6 – Training Sources Contents**

|                                | Material <sup>a, b</sup>              | Training Sources (grams) |
|--------------------------------|---------------------------------------|--------------------------|
| <b>Radioisotope</b>            | <sup>238</sup> Pu                     | 3.5                      |
|                                | <sup>239</sup> Pu <sup>c</sup>        | 190                      |
|                                | <sup>240</sup> Pu <sup>d</sup>        | 25                       |
|                                | <sup>241</sup> Pu <sup>c</sup>        | 7                        |
|                                | <sup>242</sup> Pu                     | 10                       |
|                                | <sup>241</sup> Pu + <sup>241</sup> Am | 7                        |
|                                | <sup>243</sup> Am                     | 6.63                     |
|                                | <sup>252</sup> Cf                     | 2.6 × 10 <sup>-7</sup>   |
|                                | <sup>248</sup> Cm                     | 5.7 × 10 <sup>-6</sup>   |
|                                | <sup>237</sup> Np                     | 10                       |
|                                | <sup>232</sup> Th                     | 10,000                   |
|                                | <sup>232</sup> U <sup>c</sup>         |                          |
|                                | <sup>233</sup> U <sup>c</sup>         |                          |
|                                | <sup>234</sup> U                      | 10                       |
|                                | <sup>235</sup> U <sup>c</sup>         | 500/350 <sup>f</sup>     |
|                                | <sup>236</sup> U                      | 1                        |
| <sup>238</sup> U               | 2,000                                 |                          |
| <b>Impurities <sup>e</sup></b> | (unit) →                              | (ppm)                    |
|                                | Be                                    | 1,500                    |
|                                | Al                                    | 150                      |
|                                | Mg                                    | 500                      |
|                                | Na                                    | 300                      |
|                                | F                                     | 200                      |
|                                | Ca                                    |                          |
|                                | Fe                                    |                          |
|                                | Cr                                    |                          |
| <b>Total Mass (kg)</b>         | Radioactive Materials                 | 12.75                    |
|                                | Impurities                            | 0.034                    |
|                                | All Contents                          | 12.78                    |

Notes for Table 6

- a All contents shall be dry.
- b Pu/U content bulk density shall be no greater than 19.84 g/cc and no less than 2.0 g/cc.
- c Nuclide classified as “fissile” per DOE Good Practices Guide, Criticality Safety Good Practices Program, Guide For DOE Nonreactor Nuclear Facilities, DOE G 421.1-1, 3.79 Fissile Nuclide, 8-25-99.
- d <sup>240</sup>Pu shall be greater than <sup>241</sup>Pu.
- e The Al, Mg, Na, and F limits may be increased on a ppm basis for an equal decrease in the Be content limit.
- f The 350 gram limit is imposed if the combined total <sup>239</sup>Pu mass plus <sup>241</sup>Pu mass equals or exceeds 10 grams

- (i) The Dual-3013 contents are identified in Table 7, Content Envelopes (Per 3013 Container), and are solid form as oxides. Contents in liquid form are not permitted. The total content mass listed in Table 7 applies to each 3013 Container. The Total Mass permitted is 8.8 kg of RAM as 10 kg of oxide per package. The total content mass listed in Table 7 does not include the associated packaging configurations discussed in Addendum Sections 1.2.2.1 and 1.2.2.2 of Addendum 7 [See 5(e)13)]. Requirements for the Dual-3013 Configuration contents and payload configuration are the following:
- The maximum allowable radioactive decay heat rate is 19 watts per 3013 Container and 38 watts total per Package
  - Except as stated in Table 7, small concentrations (<1000 ppm each) of other actinides, fission products, decay products, and neutron activation products are permitted. Assessment of these impurities may be based on process knowledge.
  - Except as stated in Table 7, inorganic material impurity quantities of less than 100 ppm each are permitted as long as the total mass is less than 0.1 weight percent of the total content mass. Assessment of these impurities may be based on process knowledge.
  - The maximum weight of the payload (everything that goes into the 6CV (containment vessel), including radioactive contents, the 3013 Spacer, convenience cans, contamination control devices, packing materials, spacers, etc.) is not to exceed 77.7 lb.

A typical Dual 3013 packing configuration within the 6CV for plutonium oxide contents is shown in Figure 8. In addition to the isotopic and chemical content restrictions listed in Table 7 and the configuration criteria listed in Section 1.2.2.1.1 of Addendum 7 [See 5(e)(13)], the following conditions apply:

- The 3013 Spacer must be used.
- The Heat Dissipation Sleeve must be used.
- Atmosphere within the 6CV shall be diluted to least 75% CO<sub>2</sub> per Section 7.1.2 of Addendum 7 [See 5(e)(13)].
- The 3013 Container (consisting of the outer can, the inner can, and the convenience can), shall be inerted with helium or nitrogen such that oxygen content in all void spaces is no greater than 5% by volume at the time the outer 3013 Container is sealed (welded closed).

The 3013 Containers shall consist of

| <u>Component</u> | <u>Design Authority</u>    | <u>Drawing</u>           |
|------------------|----------------------------|--------------------------|
| Convenience Can  | MOX Services               | DCS01 ZMJ DS PLG M 61241 |
| Inner 3013 Can   | LANL                       | 90Y-219875               |
| Outer Can        | British Nuclear Fuels, Ltd | M-PV-F-0017              |

- Equivalent 3013 Container configurations may be used with the prior authorization of the 9977 Design Authority.
- Aluminum foil or peanuts may be used as dunnage in place of either 3013.

**Table 7. Content Envelop (Per 3013 Container)**

|                                        | Material <sup>a, b, c</sup>           | Pu Oxide<br>"Maximum<br>Impurities" |
|----------------------------------------|---------------------------------------|-------------------------------------|
| Fissile Material<br>(Maximum Weight %) | <sup>236</sup> Pu                     | 1 x 10 <sup>-7</sup>                |
|                                        | <sup>238</sup> Pu                     | 0.05                                |
|                                        | <sup>239</sup> Pu <sup>d</sup>        | 95                                  |
|                                        | <sup>240</sup> Pu <sup>e</sup>        | 9                                   |
|                                        | <sup>241</sup> Pu <sup>d</sup>        | 1                                   |
|                                        | <sup>242</sup> Pu                     | 0.1                                 |
|                                        | U <sup>f</sup>                        | 50                                  |
|                                        | <sup>241</sup> Pu + <sup>241</sup> Am | 1                                   |
|                                        | <sup>237</sup> Np                     | 0.05                                |
| Impurities<br>(grams)                  | Be                                    | 0.44                                |
|                                        | Al                                    | 0.66                                |
|                                        | Mg                                    | 2.2                                 |
|                                        | Na                                    | 1.32                                |
|                                        | F                                     | 1.1                                 |
|                                        | B                                     | 2.2                                 |
|                                        | Li                                    | 2.2                                 |
| Total<br>Mass<br>(kg)                  | Radioactive<br>Materials              | 4.4                                 |
|                                        | Impurities                            | 0.082                               |
|                                        | All Contents                          | 5.0                                 |

Table 7 Notes.

- a All contents shall be dry.
- b Pu/U content bulk density shall be no greater than 7 g/cc and no less than 2.0 g/cc.
- c Contents shall be stabilized in accordance with DOE-STD-3013, Section 6.1.1.
- d Nuclide classified as "fissile" per DOE Good Practices Guide, Criticality Safety Good Practices Program, Guide For DOE Nonreactor Nuclear Facilities, DOE G 421.1-1, 3.79 Fissile Nuclide, 8-25-99.
- e <sup>240</sup>Pu shall be greater than <sup>241</sup>Pu.
- f All isotopes except <sup>232</sup>U, which is limited to 1 x 10<sup>-7</sup> weight percent

The contents to be shipped in the Model 9977 package shall consist of not more than 10 kg (22.05 lb) of PuO<sub>2</sub>. The PuO<sub>2</sub> is placed in one or Dual-3013 container assemblies, with not more than 5 kg (11.02 lb) per 3013 container assembly. The amount of fissile material allowed in the 9977 package is 4.4 kg (9.7 lb) per 3013 container assembly, for a total of 8.8 kg (19.4 lb) in the CV.

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(c) Criticality Safety Index (CSI)

The CSI for package with Content Envelope C.1 or ICE is zero (CSI=0).

The CSI for the package with Content Envelope AC.1 through AC.5 is 1.0 (CSI=1.0).

The CSI for package with AGR-1 Compact is zero (CSI=0).

The CSI for package with Type 4 (Sources) contents is zero (CSI=0).

The CSI for package with Training Sources contents is 1 (CSI=1).

The CSI for package with Dual-3013 contents is 1.0 (CSI=1.0).

(d) Conditions:

- (1) The contents shall have a maximum decay heat generation rate of:
  - 19 Watts for all contents/configurations; unless otherwise restricted below,
  - 19 Watts per 3013 Container and 38 watts total per Package in the Dual 3013 configuration,
  - 15 Watts for a package identified with a greater than 1-year periodic maintenance,
  - 6 Watts in the SGQ-SC1 configuration,
  - 3 Watts in the SGQ-SC2 configuration, and
  - 3.5 Watts in Training Sources Engineered Container configuration.
- (2) The maximum weight of the payload (everything that goes into the 6CV, including radioactive contents, convenience cans, contamination control devices, packing materials, spacers, etc.) is not to exceed 100 lb except for the Dual 3013 configuration where the maximum weight of the payload shall not exceed 77.7 lbs. The maximum allowable gross shipping weight of the 9977 package is 350 lb.
- (3) The Model 9977 Package must be shipped in a closed conveyance.
- (4) Transport of fissile material by air is not authorized. In addition, for Dual 3013 configuration shipments shipment by water is not authorized.
- (5) In addition to the requirements of Subparts G and H of 10 CFR Part 71, and except as specified in section 5(d) of this certificate, each package must be fabricated, acceptance tested, operated, and maintained in accordance with the Operating Procedures requirements of Chapter 7, Acceptance Tests and Maintenance Program requirements of Chapter 8, and packaging-specific Quality Assurance requirements of Chapter 9 of the SARP [See 5.(e)(1)] as supplemented by the Addendums [See 5.(e)(2), 5.(e)(4), 5.(e)(7), 5.(e)(11), 5.(e)(12), and 5(e)(13)] and the Applications [See 5.(e)(3), 5.(e)(8), and 5.(e)(9)].
- (6) For the AGR-1 fuel compacts, the requirements specified in Section 1.2.2.2.2, and in Table A.1.2, of the Addendum [5(e)(4)], must be followed, along with the specific procedures outlined in Steps 1, 2, 6, 8, and 12 of Section 7.1.1.2 of the Addendum [5(e)(4)]. The documentation packages for the Q items, numbered as 17–20, in Table A.App.8.2.1 of the Addendum [5(e)(4)], Dimensions/Materials Requiring Independent Verification Records, must be supplied by the Site directing fabrication to Savannah River National Laboratory as the Design Authority/Design Agency.
- (7) If the option is chosen to attach a DOE ARG-US RFID tag to the 9977 packaging, the operating procedures must follow the additional steps per Chapter 7 in Addendum [See 5(e)(5)], and the guide to RFID monitoring system [See 5(e)(6)]. The RFID guide contains a copy of the

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Material/Product Safety Data Sheet for the batteries used in the DOE ARG-US RFID tag, which provides guidance on the safe use of the batteries.

- (8) For the Type 4 (Sources) contents, the requirements specified in Section 1.2.2.2.1, and in Table A.1.2, of the Addendum [5(e)(4)], must be followed, along with the specific procedures of Section 7.1.1.2 of the Addendum [5(e)(4)]. The documentation packages for the Q items, numbered as 17–30, in Table A.App.8.2.1 of the Addendum [5(e)(4)], Dimensions/Materials Requiring Independent Verification Records must be supplied by the Site directing fabrication to Savannah River National Laboratory as the Design Authority/Design Agency.
- (9) Verification of the pre-shipment containment integrity of the containment system, on both the O-ring seal and the Leak Test Port Plug, shall be accomplished using either the pressure rise method or the pressure drop method of testing as specified in ANSI N14.5-1997.
- (10) The following conditions apply to the installation of a DOE ARG-US RFID tag on a 9977 packaging to allow for the extension of the maintenance interval:
  - (a) The maximum allowable radioactive decay heat rate for the 9977 package is 19 watts, except for extension of the packaging periodic maintenance interval, in which case the maximum allowable radioactive decay heat rate is limited to 15 watts.
  - (b) The user shall verify the installation of proper O-rings (i.e., GLT vs. GLT-S) and record the date of installation, e.g., 9977/GLT (or GLT-S)/xx/xx/201x, in the memory of the ARG-US RFID tag.
  - (c) During both use (loading, shipment, and unloading) and storage (loaded and empty) of the 9977 packaging, the containment vessel (CV) must remain sealed over the entire approved extended maintenance interval. In the event that operations require the CV to be opened, then the old O rings shall be replaced with new O-rings, all the requirements for the extended maintenance interval described in the SARP Addendum 4 shall be complied with for the new O-rings, and the sealing time shall be re-initialized to zero.
  - (d) The extension of the packaging periodic maintenance interval is to a maximum of five (5) years for the 9977 packaging using the Viton GLT O-rings; and to a maximum of two (2) years for the 9977 packaging using the Viton GLT-S O-rings as shown in Drawing R-R2-G-00042, Item 8. If the ongoing O-ring fixture long-term leak performance testing shows any GLT and GLT-S O-ring failures at 200°F, notify the Headquarters Certifying Official within 72 hours.
  - (e) The user of this CoC for extension of packaging periodic maintenance interval shall complete the prescribed training to become qualified and to be certified for operation of the RFID temperature monitoring system. The training course will be administered by Argonne National Laboratory on behalf of the Headquarters Certifying Official.
  - (f) When a temperature-sensing DOE ARG-US RFID tag is attached to a 9977 packaging, it shall be verified to be functional in accordance with the Operating Procedures requirements of Addendum 4 [See 5(e)(12)]. If a failure of the RFID tag or the temperature recording system results in a loss of temperature data for a duration  $\geq 72$  hours, then the packaging shall have a Nonconformance Report issued against it and be tagged and segregated until the disposition of the Nonconformance Report has been approved by both the 9977 Design Authority and Headquarters Certifying Official.

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- (11) The following conditions apply for Dual 3013 shipments in the 9977 packaging:
- (a) The 3013 Container (consisting of the outer can, the inner can, and the convenience can) shall be inerted with helium or nitrogen such that oxygen content in all void spaces is no greater than 5% by volume at the time the outer 3013 Container is sealed (welded close).
  - (b) In addition to the radioactive material and impurity mass loading limits per 3013 container assembly (Table 7), the PuO<sub>2</sub> in the 9977 package shall be limited to a total of 10kg (22.05 lb) and the maximum amount of fissile material allowed in the package shall be 8.8 kg (19.4 lb).
  - (c) The Heat Dissipation Sleeve and the annular 3013 Spacer must be used for the 9977 package with Dual-3013 containers. Verify that the Heat Dissipation Sleeve and the annular 3013 Spacer have been properly installed.
  - (d) The bulk density of the PuO<sub>2</sub> shall be >2g/cm<sup>3</sup> and < 7g/cm<sup>3</sup>.
  - (e) Seal time must be 12 months or less, where seal time is defined as the length of time that the shipment must be complete after the 9977 CV is sealed.
  - (f) The void space within the CV shall be backfilled with ≥ 75% by volume carbon dioxide gas prior to shipment.
  - (g) If the measured Transport Index is greater than 10, the package must be transported by “Exclusive Use” shipment, and/or additional; 3013 container mass loading restrictions or impurity control measures may be used to reduce the dose rates.
- (12) The ARG-US RFID may be used as a Tamper-Indicating Device Seal [See 5(e)(14)].
- (13) Previous revisions of this DOE Certificate of Compliance maybe used until July 31, 2013.
- (e) References
- (1) *Safety Analysis Report for Packaging, Model 9977 B(M)F-96*, S-SARP-G-00001, Revision 2, August 2007
  - (2) *Safety Analysis Report for Packaging, Model 9977 Addendum 2, Justification for Metal Contents*, S-SARA-G-00005, Revision 1, December 16, 2008.
  - (3) *Application for Contents Amendment for Shipping Isentropic Compression Experiment (ICE) Apparatus in 9977 Packaging*, National Nuclear Security Agency Memorandum from Paul T. Mann, Facility Operations Division, NA-172.1, to James M. Shuler, Office of Packaging and Transportation Safety, EM-63, Revision 2, February 20, 2009.
  - (4) *Safety Analysis Report for Packaging, Model 9977 Addendum 3, Justification for Small Gram Quantity Contents*, S-SARA-G-00006, Revision 4, March 2010.
  - (5) *Safety Analysis Report for Packaging, Model 9977Addendum 4, Justification for Use of the Radio Frequency Identification (RFID) System*, S-SARA-G-00010, Revision 0, February 2010

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| 9977               | 12           | USA/9977/B(M)F-96 (DOE)    | 34       | 34              |

- 6) Guide to the RFID Monitoring System (Models 9975, 9977, and 9978 Packages), Argonne National Laboratory, ANL/DIS-09-5, December 3, 2009 and its Supplements.
- (7) *Safety Analysis Report for Packaging, Model 9977 Addendum 5, Justification for Training Sources Contents*, S-SARA-G-00009, Revision 2, May 2010
- (8) Application for Amendment for Shipping Revised Sleeve and Plug Design in the 9977 Packaging, NNSA memorandum from Paul Mann to James M. Shuler, Manager DOE PCP, June 29, 2010.
- (9) Memo from Paul Mann to J. Shuler, "ACTION: Application for Contents Amendment for Shipping Alternate Radioisotopic Thermoelectric Generator (RTG) Assembly Configuration in 9977 Packaging," November 22, 2010.
- (10) Memo from Paul Mann to J. Shuler, "ACTION: Application for Contents Amendment for Shipping Training Source Contents in 9977 Packaging," November 22, 2010.
- (11) Letter Amendment Request for the 9975-85, 9975-96, 9977, and 9978, COR-OM-11/15/2010-301010, submitted to Dr. Jim Shuler, Environmental Management, by the National Nuclear Security Administration (NNSA), Livermore Site Office (November 17, 2010).
- (12) *Justification for Use of the Radio Frequency Identification (RFID) System and Extension of Packaging Periodic Maintenance Interval*, Safety Analysis Report for Packaging Model 9977, Addendum 4, S-SARA-G-00010, Revision 5, February 2012, Savannah River National Laboratory.
- (13) *Safety Analysis Report for Packaging Model 9977, Addendum 7, Justification for Dual 3013 Contents*, S-SARA-G-00012, Revision 3, July 2012.
- (14) *DOE Packaging Certification Program Qualification/Accreditation of ARG-US Tag as a TID Seal*, July 30, 2012.