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Shipment of Non-traditional Contents in the 9977 Type B Package

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ABSTRACT
The 9977 is a certified Type B Packaging authorized to ship uranium and plutonium in metal and oxide forms. These materials are typically confined within metallic containers designed for ease of handling and to prevent the spread of contamination. The Pacific Northwest National Laboratory (PNNL) uses Pu and U sources for the training of domestic and international customs agents in the identification and detection of radioactive materials (RAM). These materials are packed in polycarbonate containers which permit the trainees to view the RAM. The safety basis was made to authorize the use of these unusual containers.

Background

Content containers are typically designed and used for radioactive material (RAM) confinement, handling convenience, and contamination control in their generating or use locations/facilities.

These content containers maybe qualified by their owners as Sealed Sources. A "Sealed" Source is a container that has been tested per ANSI/HPS N43.6-2007 to remain leaktight after drops from 1.5 meters unto an unyielding surface. But, since these "Sources" not tested to the "packaging criteria" they are not credited with performing any Packaging specific safety or compliance function. Since the Type B Packaging provides the physical protection and containment required by Title 10 of the Code of Federal Regulations Part 71, the content container is not credited for providing any containment.

The Pacific Northwest National Laboratory (PNNL) uses plutonium and uranium sources for the training of domestic and international customs agents in the identification and detection of RAM. These "Training Source" materials are an extension of the "Samples and Sources" Content Envelope previously authorized for shipment in the Model 9978 Packaging. The exception is that for the Training Source content the ^{241}Pu plus ^{241}Am mass has been maximized within the dose rate limits. These materials may be packed in polycarbonate containers which permit the trainees to view the RAM. See Figure 1. Typical containers are shown for information only. The analyses presented in the safety basis [Ref 1] bounds the actual containers used. The essential requirements for safe transport of such materials is that they be properly contained, are subcritical at all times, and do not expose the public, workers, or the environment to radiation dose levels greater than those permitted by the applicable regulations.

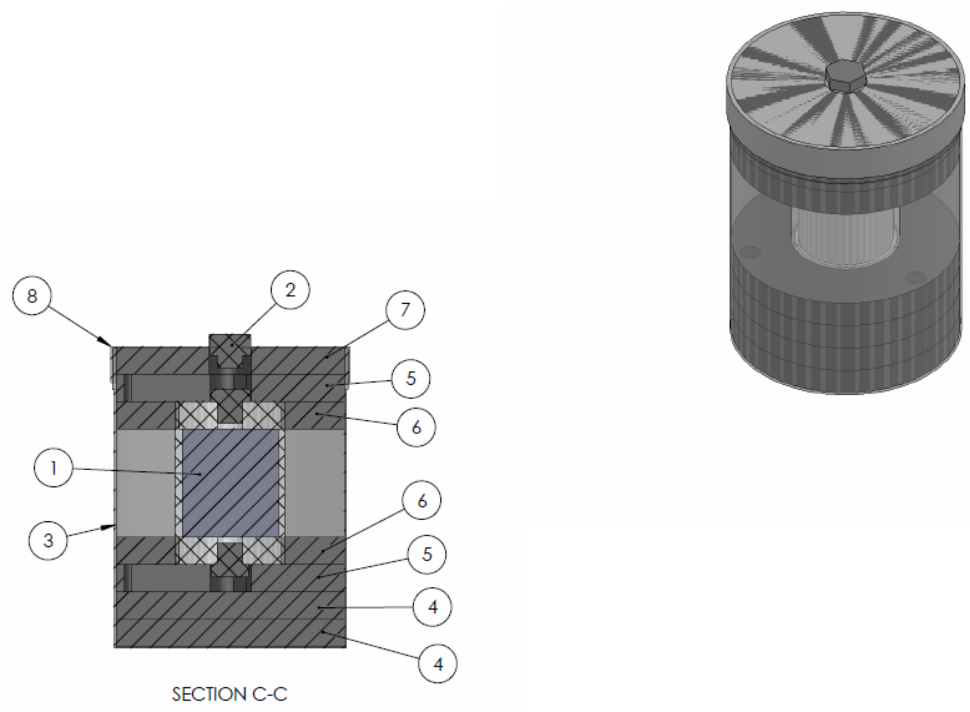

Figure 1 – Typical PNNL Training Source (125-gram HEU shown)

What are the requirements of a content container?
A content container is primarily used to provide confinement, if not actual containment, of the RAM. It keeps the RAM in a controlled location/configuration, preventing its release and the spread of contamination. In order to provide confinement the container must be robust, have a closure of some type, be compatible chemically and physically with the contents, and not degrade within its shipping window. The container must also be compatible with the package within which it and its RAM will be shipped.

Typical content containers are “cans” made of stainless or tin plated steels. These “cans” are then typically closed with lids that incorporate crimp-seals (as in Food-Pack Cans), welds (as defined for the DOE-STD-3013 Inner and Outer Containers), threaded fittings (the Los Alamos National Laboratory ICE Container), bolted flanges (the Conflat fitting LANL uses for the Pu Oxide samples), or bayonet closures (as in the “Hagen” can).

These containers may incorporate elastomeric seals, internally as O-Rings or externally as tape. The RAM may also be placed in plastic bagging as a contamination control feature prior to placement within the container.

Materials within the package may degrade by numerous mechanisms; chemical reactions, melting or aging due to the content decay-heat, radiolysis from the RAM, pressure or vacuum from the content gases.

For all the performance requirements and degradation processes stainless and plated steels are a good choice for content containers. Stainless and plated steels have high strength, are chemically resistant, can be machined to incorporate a closure, have a high resistance to radiation, and degrade slowly relative to shipping timeframes.

The one function where steels perform poorly is transparency, but this is not a RAM content container performance requirement. With PNNL needing their containers to perform all the typical confinement functions and including functioning as a “display” medium, an atypical container material was required.

Transparent materials are available that can be used as a RAM content container. Various plastics are available that have sufficient strength to confine the RAM and withstand the impacts and vibrations of the Normal Conditions of Transport (NCT). These plastics are also chemically inert, are physically stable at the temperatures encountered with the package, can withstand moderate gases and pressure, and do not degrade quickly within the contents radiation field. However, these plastics are typically weaker then metals, degrade and evolve gasses when irradiated and heated.

RAM Packaging Performance Requirements

A RAM Package must perform, in the broadest terms, the following three functions as defined in Title 10 of the Code of Federal Regulation Section 71:

Containment - Package Containment Vessel shall be designed, constructed, and prepared so that, under NCT, there will be no loss or dispersal of radioactive contents. Likewise, the Containment Vessel shall be designed, constructed and prepared so that, during the HAC, there is no escape of radioactive materials can occur in excess of the A_2 value in one week.

Criticality - The Package must remain subcritical at all times.

Shielding - The Package must maintain dose rate limits for an undamaged package which are 200 mrem/h at the surface of the package, 10 mrem/h at 1-meter from the accessible surface of the package, and 1 rem/h at 1-meter from the surface of a damaged package after a hypothetical accident.

The 9977 Packaging has been analyzed with the proposed PNNL “Training Source” contents [Ref 1] and demonstrated to meet the 10CFR71 regulatory requirements for containment of the RAM contents, ensuring subcriticality, and maintaining the dose rate limits under all conditions.

PNNL Training Sources

The PNNL Training Sources are defined [Ref 2] in a series of drawings that illustrate/define a family of containers that may be used with a variety of RAM. These Sources typically contain the RAM materials surrounded by a tube made of polyvinyl chloride (PVC), then a layer of a shock absorbing and vibration dampening material that keeps the PVC tube centered within the assembly, and finally a polycarbonate tube which holds the assembly together. The sources vary in size from 0.625 inches in diameter and 1.4 inches long to 4.5 inches in diameter and 5.5 inches long. The sources may weigh as much as 350-grams and contain up to 200-grams of total plastics. Two packing configurations were authorized, with the bounding configuration shown in Figure 2. This configuration has 230-grams of RAM, 211-grams of plastics, 2000-grams of stainless steel, and 900-grams of aluminum dunnage.

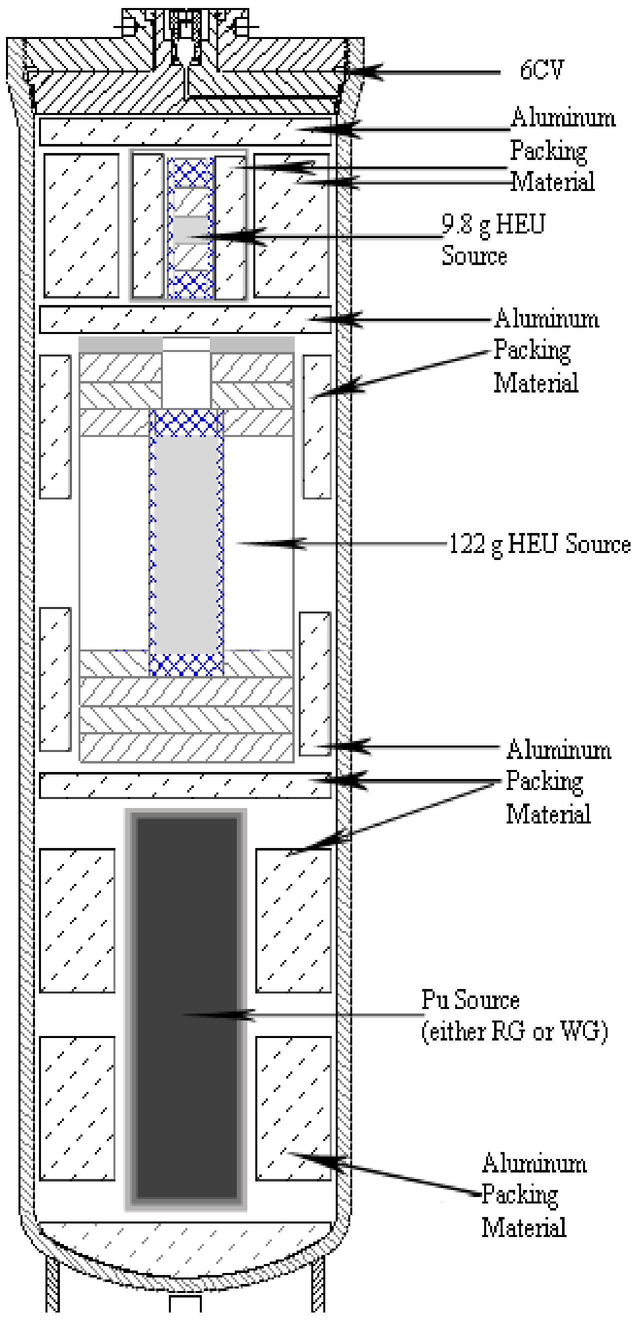

Figure 2 – PNNL Packing Configuration D in the 9977 6CV

The 9977 CV provides leaktight containment under both NCT and HAC and the Package maintains subcriticality under all conditions. The 9977 shielding analyses assumed that the content containers disappeared and so are independent of and do not require any content containers. The justification of the PNNL Training Sources developed into a review of if and how these containers affect the 9977 Packages ability to perform its safety function.

Weight

The 9977 is certified with a total content weight, the RAM contents, containers, packing materials, and dunnage, of 100 lbs. The 9977 compliance with the 10CFR71 regulatory requirements was demonstrated by testing with verification by analysis. The 9977 was drop-tested with a 100-lb steel slug simulating the contents within the 6-inch diameter Containment Vessel (6CV). The slug was loose, with no shock or vibration reducing dunnage. The positive results of this testing with a loose 100-lb slug bounds all contents for physical interaction with the 6CV. Lighter weight or softer contents will have different specific point loads than the test configuration but will be lower in severity and are therefore bounded.

Material Compatibility

The 9977 6CV is fabricated from 304L Stainless Steel and has been evaluated for its material compatibility with other grades of stainless steel, aluminum, copper, Viton rubber, and low-chloride plastics. The polycarbonate plastic materials of the Training Sources are compatible with the 6CV and are not expected to cause any degradation of the vessel.

Subcriticality

The criticality analysis of the Training Source content in the 9977 considered the most fissile radioisotopes within the content at their mass limits with the maximum moderation possible. The subcriticality of the Single Package Flooded scenario is established by maintaining the individual and combined masses below the subcritical mass limits. Since the content mass is below the subcritical limit the amount of polycarbonate within the 6CV is irrelevant.

In the dry single package and array analysis of the 9977 with its high density polyethylene shock absorbing materials the RAM mass limits of the Training Source Content are bounded by the baseline analysis [Ref 3] which considered up to 4.4-kg of ^{239}Pu in the 6CV configuration. The maximum k_{eff} for the bounding content is 0.874 for the NCT and 0.890 for HAC. These analyses were performed with the packages in the maximally moderated condition, so the presence of the polycarbonate within the 6CV will not increase the k_{eff} for these conditions. Therefore, the use of the polycarbonate materials in the Training Sources does not affect the 9977's subcriticality.

Temperature and Pressure

The greatest effect the Training Source content containers have on the 9977 safety basis is the effect the material and configuration has on the maximum temperatures and pressures within the 6CV. The 9977 6CV has a design temperature of 300 ºF and a design pressure of 800 psig. The baseline maximum 6CV NCT temperature and pressure (the Maximum Normal Operating Pressure or MNOP) with 19 watts of content decay-heat rate and insolation are 321 ºF and 41.2 psig. The polycarbonate has a lower thermal conductivity than typical metal containers. It will therefore, act as an insulator causing the contents to heat to a higher temperature. This higher content temperature could result in locally higher temperatures in some locations in the 6CV. For the Training Sources, the maximum content decay heat rate is only 3.5 watts and this results in a maximum 6CV temperature of only 236 ºF, well below the design temperature.

Table 1 - Maximum Pressures for 6CV under NCT and HAC

Condition	SARP Max Pressure (psig)	SARP Max Pressure (Margin)	Training Sources Max Pressure (psig)	Training Sources Max Pressure (Margin)
NCT	41.2	95%	397	50%
HAC	35.0	96%	505	37%
Design Limit	800			

Note: Margin is defined as [1-(actual/allowable)]×100%.

The Training Source containers have a greater effect on the maximum pressure within the 6CV. The calculation of the theoretical maximum pressure within the 6CV considers the maximum temperature, the free gas volume, the radiolysis of any moisture entrained in the RAM (as forming hydrogen and oxygen gases), the evolution of helium, and the radiolysis of the plastic. [Ref 4] The Maximum Normal Operating Pressure (MNOP) is calculated with the maximum temperature, a minimum volume (based on the maximum content), and 100 grams of plastic. The pressure calculation for the Training Source Contents was conservatively based on a decay-heat rate of 10.5 watts. The maximum mass of 2-kg of polycarbonate not only consumes more free gas volume than was previously considered, but it liberates more gases. The analysis also considered a bounding metal mass of 10-kg, as either content container or dunnage materials. The mass of metal is significant only in that it consumes free volume within the 6CV. The maximum NCT pressure calculated for the bounding Training Source configuration is 397 psig. While this is 10 times the baseline MNOP it is still less than half of the 6CV's design pressure.

Summary

The inclusion of the PNNL Training Source Contents into the 9977 Packaging imposed unique conditions previously unanalyzed. The use of polycarbonate as a content container material, while different from any configuration previously considered, does not raise any safety issues with the package which continues to operate with a large safety margin for temperatures, pressures, containment, dose rates, and subcriticality.

References

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