Safety Evaluation Report for the
Justification for Training Sources Contents
Safety Analysis Report for Packaging
Model 9977-96
Addendum 5

S-SARA-G-00009, Revision 2

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Prepared by: James M. Shuler Date: 7/15/10
James M. Shuler
Manager, DOE Packaging Certification Program
Office of Packaging and Transportation (EM-45)
Office of Environmental Management

Approved by: Frank Marcinowski Date: 7/16/10
Frank Marcinowski
Headquarters Certifying Official
Deputy Assistant Secretary for Technical and Regulatory Support (EM-40)
Office of Environmental Management

OVERVIEW

This Safety Evaluation Report (SER) summarizes the results of the Department of Energy (DOE) Packaging Certification Program (PCP) Staff's review of the Model 9977-96 Package, Addendum 5, Revision 2, for the proposed Training Sources contents. The Training Sources contents may include radioactive isotopes (^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{241}Am, ^{243}Am, ^{252}Cf, ^{248}Cm, ^{237}Np, ^{232}Th, ^{234}U, ^{235}U, ^{236}U, ^{238}U), with impurities (such as Be, Al, Mg, Na, and F). These new contents will be authorized for shipment in the Model 9977-96 Package, supplementing the existing Revision 2 to the Safety Analysis Report for Packaging (SARP), once Addendum 5, *Justification for Training Sources Contents*, is accepted by the certifying official, EM-40, and the existing Certificate of Compliance (CoC) is revised, reflecting the added contents. Existing Content Envelopes for the Model 9977-96 Package include heat sources in food-pack cans or in radioisotope thermoelectric generators (RTGs), neptunium metal, a beryllium-reflected plutonium ball, plutonium/uranium metal at 25% and 50% maximum ^{240}Pu, respectively, and uranium metal at limits of 95% and 100% ^{235}U, respectively. The percentages are of total radioactive material mass. The Isentropic Compression Experiment (ICE) apparatus and AGR fuel compacts are additional content of the Model 9977-96 Package SARP. The latest content added to the Model 9977-96 Package is Type 4 Contents "Orphaned Sources," as described in Addendum 3, Revision 4.

Addendum 5 was prepared by Savannah River Packaging Technology, Savannah River National Laboratory, Savannah River Nuclear Solutions, LLC, Savannah River Site, in support of work being performed by Los Alamos National Laboratory.

The Model 9977-96 Package is currently certified under two CoCs, i.e., USA/9977/B(M)F-96 (DOE) and USA/9977/B(M)F-96 (DOE-S/T-1), covering transportation and periodic and extended maintenance, respectively. For transportation, the applicable SARP is S-SARP-G-0001, Revision 2 (August 2007). Extended maintenance is covered by Addendum 1, *Justification for DNDO Contents*, S-SARA-G-00003, Revision 2 (October 2008).

The new Content Envelope and container configurations will be incorporated into the next revision to the Model 9977-96 Package SARP.

This SER addresses only Training Sources contents and hereafter, the Training Sources content may be referred to as *Sources*.

Chapter 1: General Information

This SER documents the DOE PCP Staff's review of, *Justification for Training Sources Contents* Addendum 5, S-SARA-G-00009, Revision 2 (May 2010)[1] (the Submittal) prepared for the DOE by Savannah River Packaging Technology, Savannah River National Laboratory, Savannah River Nuclear Solutions, LLC, Savannah River Site, to support the shipment of a variety of so-called *Training Sources*, using the Model 9977-96 Package. This section of the SER covers the review of the General Information provided in Chapter 1 of the Submittal.

The Submittal is an Addendum to S-SARP-G-00001, Revision 2 (August 2007).[2] Previous Addenda to the Model 9977-96 Package SARP include: Addendum 1, Revision 2, *Justification for DNDO Contents*, S-SARA-G-00003;[3] Addendum 2, Revision 1, *Justification for Metal Contents*, S-SARA-G-00005;[4] and Addendum 3, Revision 4, *Justification for Small Gram Quantity Contents*, S-SARA-G-00006.[5] The safety basis described in the Submittal addresses specific supplements to the currently approved SARP. The Model 9977-96 Package is currently certified for transportation by the DOE under Revision 4 to the Certificate of Compliance (CoC), [6] and for storage/transportation under Revision 0 to the CoC. [7]

The new Content Envelope, *Training Sources*, will allow the 9977-96 Package to be used to ship these Training Sources between DOE sites and Laboratories in support of general programs. Training Sources contents may include radioactive isotopes (^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{241}Am, ^{243}Am, ^{252}Cf, ^{248}Cm, ^{237}Np, ^{232}Th, ^{234}U, ^{235}U, ^{236}U, ^{238}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 engineered top, or a Training Source Engineered Container.

The Submittal addresses nonexclusive use shipments, and the maximum weight of the payload remains at 100 pounds.

Findings

The DOE PCP Staff identified numerous instances of editorial errors, reference and citation errors, and organizational concerns. After completing their review of the entire document the DOE PCP Staff has determined that all of the technical information required for the performance of their review was, in fact, included. Based on the technical information provided, therefore, the DOE PCP Staff recommends that a new CoC be issued to allow for the shipment of the Training Sources contents.

Conditions of Approval

The DOE PCP Staff has also concluded that the following additional conditions of approval need to be added to the existing CoC[6] for the approval of this request:

- The maximum masses for the proposed Training Sources contents are limited to the masses noted in Table A.1.1 of the Submittal;
- The Packaging Configuration requirements specified in Addendum Table A.1.2 of the Submittal, i.e., *Summary of Requirements*, must also be followed; and
- The Packaging Configuration requirements specified in Addendum Appendix 1.1 of the Submittal, i.e., *Configurations for Possible Shipments in 9977 Shipping Containers*, must be followed.

Chapter 2: Structural Evaluation

This section of the SER covers the assessment of the Structural Evaluation information provided in Chapter 2 of the Submittal.[1]

Details of the items reviewed are noted above in Chapter 1. The results of the structural review are discussed below.

In Chapter 2, the Submittal presents the following information and conclusions concerning structural requirements and performances that the Model 9977 Packaging must comply with for shipping the Training Sources contents:

- The maximum weight of the present (Training Sources) contents is only 55 pounds, versus the design payload weight of 100 lb. Thus, the overall impact performance of the package has a large margin of safety for the present contents. The Model 9977 Packaging was designed for contents with a decay heat of 19 watts, which is considerably higher than the 3.5 watt of the Training Sources contents. Therefore, the Model 9977 Packaging has an additional thermal margin of safety for the Training Sources contents.

- The margin of safety in impact and thermal performance will assure the structural integrity of the containment vessel. However, the margin m*ay not* exist in the structural performance of the Training Sources containers, since the containers have not been evaluated for structural integrity during transport. Consequently, the DOE PCP Staff has considered the risk of container breakage. The DOE PCP Staff concluded that none of the containers and contents fragments can damage the 9977 containment vessel. This is because the containment vessel, the contents, and the contents containers have similar mechanical properties, and the containment-vessel material and design are the strongest. In addition, the foam and aluminum foil spacers will mitigate the harmful interaction of the vessel, the containers, and the contents.

Findings

Based on the review of the statements and representations in Rev. 2 of the Submittal, the DOE PCP Staff has concluded that the packaging design has been adequately described to meet the structural requirements of 10 CFR 71.

The DOE PCP Staff finds the information and conclusions in Chapter 2 acceptable. DOE PCP concurs that the 9977 Packaging with the Training Sources contents has adequate structural performance to meet the safety requirements of 10 CFR 71.

Conditions of Approval

DOE PCP has concluded that no additional structurally-related conditions of approval need to be added to the existing CoC for the approval of this request.

Chapter 3: Thermal Evaluation

This section of the SER covers the review of the Thermal Evaluation information provided in Chapter 3 of the Submittal and Appendices of the Submittal.[1]

Details of the items reviewed are noted above in Chapter 1. The results of the thermal review are discussed below.

The Model 9977-96 Package is presently authorized for the shipment of contents in RTGs, Food-Pack Cans, DOE-STD-3013 Containers, and Engineered Containers.[2] The maximum decay heat from radioactive contents is limited to 19 watts per package. The Training Sources contents described in this addendum is an extension of Content Envelope C.6, authorized for shipment in the Model 9978 Packaging. The Applicant provided two typical Training Source configurations, represented pictorially in Figures A.1.1 and A.1.2 in the submittal. The thermal evaluation,[8] and the associated review for this SER, are based on the configuration where a typical Training Source content is located in the middle of CV.

The individual Training Sources contents shall:

- Have no more than 3.5 Watts of decay-heat generation;
- Contain less than 2 kg of plastic or other organic packing material susceptible to out-gassing inside 6CV;
- Not have a chemical reaction with the containment vessel or cause corrosion; and
- Be limited to Training Source contents that do not produce gases.

The free volume in the void space in the aluminum foam insert at the bottom of the 6CV must be greater than 15.28 in^3.

The applicant did numerical simulation for the NCT temperature distribution with and without solar heating. Compared with the data of 9977 Revision 2, the temperatures in the CV for this Addendum are lower under NCT, due to the lower decay heat.

For the MNOP, the applicant utilized test data from the H-1616 Container to estimate the pressure increase for the out-gassing of the plastics,[9] and modified their estimates with a maximum mass of 2 kg (4.4lbs), and free volume of 15.28 in^3. The DOE PCP Staff has confirmed the out-gassing pressure calculations, and verified that the assumptions are reasonable. The safety margin for the MNOP is about a factor of two (2).

Findings

Based on the review of the statements and representations in the Submittal, the DOE PCP Staff has concluded that the packaging design has been adequately described to meet the requirements of 10 CFR 71.

Conditions of Approval

DOE PCP has concluded that no additional thermally-related conditions of approval need to be added to the existing CoC for the approval of this request.

Chapter 4: Containment

This section of the SER covers the review of the Containment information provided in Chapter 4 of the Submittal.[1]

Details of the items reviewed are noted above in Chapter 1. The results of the containment review are discussed below.

The proposed addition of the Training Sources contents to the Model 9977-96 Package SARP does not increase the impact loading on the containment vessel, the temperatures that must be sustained, or the pressure that must be contained. Therefore, package containment leaktight

performance, in accordance with ANSI Standard N-14.5,[10] as documented in the existing Model 9977-96 Package SARP, is still valid for the Training Sources contents addition.

Findings
Based on the review of the statements and representations in the Submittal, the DOE PCP Staff has concluded that the packaging design has been adequately described to meet the requirements of 10 CFR 71.

Conditions of Approval
DOE PCP has concluded that no additional containment-related conditions of approval need to be added to the existing CoC for the approval of this request.

Chapter 5: Shielding Evaluation

This section of the SER covers the review of the Shielding Evaluation information provided in Chapter 5 of the Submittal.[1]

Details of the items reviewed are noted above in Chapter 1. The results of the shielding review are discussed below.

Shielding Evaluation
This section of the SER reviews the adequacy of the Model 9977-96 Package design to meet the external dose rate limits prescribed in 10 CFR Part 71, when Training Sources contents are placed in the 6CV. The mass limits for individual isotopes that comprise the Training Sources are presented in Table A.1.1 of the Submittal.

The shielding analyses performed for the Model 9978 Package used the more conservative 9977 Model, and demonstrated compliance with the external radiation level limits prescribed in 10 CFR Part 71. Thus, the original analyses for the Contents C6 in the 9978 package are valid for the same contents in the 9977 package. The applicant has demonstrated, via a set of conservative calculations, that the addition of 4g of Am-241 to the C6 Contents will still meet the regulatory requirements for dose rates for non-exclusive use shipments. The DOE PCP Staff has confirmed that these analyses are valid, and that the 9977 Package with the Training Sources contents will meet the regulatory requirements with the addition of 4g of Am-241 to the contents originally analyzed. Thus, these contents prescribe individual limits for isotopes that constitute the Training Sources.

Findings
Based on the review of the statements and representations in the Submittal, and independent estimates by the DOE PCP Staff, DOE PCP has concluded that the packaging design has been adequately described to meet the external radiation requirements of 10 CFR 71 for the Training Sources contents, provided the individual mass limits of the isotopes in Table A.1.1 of the Submittal are not exceeded.

Conditions of Approval
The CoC must contain the restriction that the individual mass limits of the isotopes presented in Table A.1.1 of the Submittal not be exceeded when these Training Sources are shipped. No additional conditions of transport are required to be added to the existing CoC for the shipment of the Training Sources contents.

Chapter 6: Criticality Evaluation

This section of the SER covers the review of the Criticality Evaluation information provided in Chapter 6 of the Submittal.[1]

Details of the items reviewed are listed above in the introduction to Chapter 1. The results of the criticality review are discussed below.

Criticality Evaluation

It is specified in Chapter 1 that the 9977 Addendum 5 Training Sources contents are composed of Pu-238 (3.5g), Pu-239 (190g), Pu-240 (25g), Pu-241 (7g), Pu-242 (10g), Np-237 (10g), Am-243 (6.63g), U-234 (1g), U-235 (500g), U-236 (1g), U-238 (2000g), and Th-232 (10,000g). A few other elements like Be, Al, Mg, Na, F, Ca, Fe, and Cr are present in trace quantities. The total amount of Training Sources is limited to 12.75 kg of radioisotopes, out of which 12 kg are non-fissile isotopes of Th-232 and U-238. The amount of fissile isotopes is less than 750g.

This Training Sources content is very similar to Content Envelope C.6 (Samples and Sources) for the Model 9978 Package, as is shown in Table 1.

No detailed analyses were performed for the Training Sources contents. The criticality evaluation for Training Sources contents was performed by using the bounding calculations for Content Envelope C.2 in the 9978 SARP.

As is shown in Table 1, Content Envelope C.6 in the 9978 is dominated by Pu-239 and U-235. Content Envelope C.6 also has other isotopes of Pu and U, in addition to relatively small amounts of Am, Np and relatively large amounts of thorium. Content Envelope C.6 has a maximum fissile mass of 191 grams of Pu and 500 grams of U-235 and 1,500 ppm of Be. The fissile mass of Pu-241 for the Training Sources is slightly higher by 6 grams, while it does not have any Am-241. The difference between the Training Sources contents with the Content Envelope C.6 of the 9978 is minimal, as is shown in Table 1. It was shown in the 9978 SARP that Content Envelope C.6 is bounded by Content Envelope C.2.

Table 1: Content Specifications

Isotope	9977 Addendum 5 Content (Training Sources) (grams)	9978 C.6 Content (grams)	9978 C.2 Content Pu/U metal (wt %)
CV	6"	5"	5"
Pu-238	3.5	3.5	2%
Pu-239	190	190	100%
Pu-240	25	25	25%
Pu-241	7	1	15%
Pu-242	10	10	5%
Am-241	0	3	15%
Am-243	6.63	6.63	—
Np-237	10	10	—
U-235	500*	500	100%
Total	**752.13**	**749.13**	
U-234	1	1	100%
U-236	1	1	40%
U-238	2,000	2,000	100%
Th-232	10,000	10,000	—
Be	1,500 ppm	1,500 ppm	0
Total Radioactive Material Mass	12.75 kg	12.75 kg	4.4 kg

**U-235 is only 350g when Pu-239 + Pu-241 ≥ 10g*

Single Package Analysis — The single package analysis was shown to be subcritical by using the ANSI/ANS 8.1 single-parameter subcritical limits of Pu-239 and U-235.[11] The subcritical mass limit of Pu-239 is 450 grams, while that of U-235 is 700 grams. It is also noted in the ANSI/ANS 8.1 Standard that the Pu-239 limit can be applied to a mixture of plutonium isotopes, provided that the concentration of Pu-240 exceeds that of Pu-241. This is true for the Training Sources, as is shown in Table 1. In that case, only Pu-241 shall be added to Pu-239 in computing total fissile mass. The Pu-239 mass can be made equivalent to the U-235 mass by multiplying the Pu mass with 700/450 = 1.56 ≅ 1.6 (*to be conservative*). In other words 1.6* Pu-239 mass = U-235 mass. Similarly, the U-235 mass can be made equivalent to the Pu-239 mass by dividing the U mass with 700/450 = 1.56 ≅ 1.5 (*to be conservative*). In other words U-235 mass/1.5 = Pu-239 mass.

1. When the maximum Pu-239 + Pu-241 mass is 10 grams:
   a. The total equivalent U-235 in the content is 500 + 1.6*10 =516 grams. The 516 gram (< 700 grams) of U-235 will remain subcritical in the 9977 Package.
   b. When the maximum Pu-239 + Pu-241 is 10 grams, the total equivalent Pu-239 in the contents is 10 + 500/1.5 =10 + 334 = 344 grams. The 344 gram (< 450 grams) of Pu-239 will remain subcritical in the 9977 Package.

2. When the maximum Pu-239 + Pu-241 mass is more than 10 grams:
   a. The maximum Pu-239 + Pu-241 is 190 + 7 = 197 grams, the total equivalent U-235 in the contents is 350 (*as specified in the content table*) + 1.6*197 =350 + 316 = 666 grams. The 666 gram (< 700 grams) of U-235 will remain subcritical in the 9977 Package.
   b. When the maximum Pu-239 + Pu-241 is 190 + 7 = 197 grams, the total equivalent Pu-239 in the contents is 197 + 350/1.5 =197 + 234 = 431 grams. The 431 gram (< 450 grams) of Pu-239 will remain subcritical in the 9977 Package.

There may be a small amount (1,500 ppm) of Be in the Training Sources contents. Since there is a sufficient conservatism in the analysis, it is judged that the conclusion will remain valid, even with 1,500 ppm of Be in the package. The reactivity effects of other impurities are negligible. It is to be noted that the single package analysis was performed assuming the contents in the solution form, and thereby using the solution subcritical limits instead of using the subcritical limits for metal, which are considerably higher (e.g., Pu-239 subcritical mass limit is 5.0 kg and U-235 subcritical mass limit is 20.1 kg in the solid metal form[11]). The Training Sources shall be in solid form (metal or oxide), and there shall be no free liquids as specified in Chapter 1 (see Section 1.2.2 of the Submittal). A large quantity of U-238 and Th-232 will act like a poison in the solution system, and will act like a diluent when mixed with fissile solid material. The critical mass will be reduced when U or Th are used as a reflector. However, the Training Sources content mass is an order of magnitude lower than the critical reflected mass of U or Pu in the solid form. For example, the critical mass values of U-235 and Pu-239 with thick uranium reflector are about 16 kg, and 5.7 kg, respectively.[12] It is also noted that the Content Envelope C.2 in the 9978 SARP was shown to be subcritical with 4.4 kg of Pu-metal in a 5" CV. The same conclusion is valid for solid contents in a 6" CV as well for the single package analysis. Therefore, it is concluded that the Training Sources contents shall remain subcritical in the single package of the 9977.

NCT and HAC Array Analysis — For Normal Conditions of Transport and (NCT) and Hypothetical Accident Condition (HAC) analyses, it was shown that the Training Sources content is bounded by the Content Envelope C.2 in the 9978 Packaging, assuming a fissile mass of 4.4 kg of Pu-239. The fissile mass limit for the Training Sources is much less than the 4.4 kg of Pu-239, as is shown above in Table 1. It may also be noted that that 9978 CV was conservatively assumed to be 6" for the NCT and HAC analyses in the 9978 SARP. Therefore the identical NCT and HAC analyses are also valid for the 9977 Shipping Container, which has a CV of 6" diameter, using a content of 4.4 kg of Pu-239.

The Content Envelope C.2 with 4.4 kg of Pu-239 was analyzed in detail in the 9978 SARP. Based on the fact that the limiting fissile mass of 4.4 kg was used in the NCT and HAC bounding scenarios for the Content Envelope C.2 of the 9978, it is judged that the Training Sources contents are bounded by Content Envelope C.2 of the 9978, for the HAC and NCT array analyses. The Staff concurs that no explicit analysis is required to substantiate this conclusion. There is considerable reactivity margin available for the Training Sources contents, based on its significantly lower fissile mass.

Criticality Safety Index (CSI)

The CSI for Content Envelope C.2 is 1.0 in the 9978 SARP. Since the bounding calculations (using 6 CV model) for Content Envelope C.2 in the 9978 SARP were used for the justification

of subcriticality of the Training Sources contents for 9977, the same CSI value of 1.0 can be used for 9977 with the Training Sources contents.

Code Verification and Validation

No code calculations were used for the analyses of Training Sources contents, but the analyses with the SCALE code system were used in the 9978 SARP to conclude the subcriticality of Training Sources contents. Scale code verification and validation were properly performed and documented for the bounding calculations in the 9978 SARP.

Conclusions

It is concluded that the Training Sources contents for the 9977 Shipping Container remain subcritical under the Single package, NCT and HAC scenarios with a CSI of 1.0.

Findings

Based on the review of the statements and representations in the Submittal, the DOE PCP Staff has concluded that the packaging design and bounding analyses have been adequately described to meet the requirements of 10 CFR 71.

Conditions of Approval

The new Training Sources contents for the 9977 Shipping Container can be shipped with a CSI of 1.0. DOE PCP has concluded that no additional criticality-related conditions of approval need to be added to the CoC for the approval of this application.

Chapter 7: Package Operations

This section of the SER covers the review of the Package Operations information provided in Chapter 7 of the Submittal.[1]

Details of the items reviewed are listed above in the introduction to Chapter 1. The results of the Package Operations review are discussed below.

Findings

The Package Operations Chapter provides general information and refers the user to Section 1 of the Addendum and the SARP for actions. A single line in Addendum Section 1.2.2.1.1 directs the user to Addendum Appendix A.1.1. Addendum Appendix A.1.1 is a Pacific Northwest National Laboratory May 11, 2010 memorandum addressing configurations for possible shipments in the 9977 shipping containers for the training sources addressed by the Addendum. This is a site–specific Operating Procedure for the shipment of the new Training Sources contents. Although this not in keeping with past practices, it should allow for the use of the 9977 Packaging for the shipment of the proposed Training Sources contents.

Conditions of Approval

The DOE PCP Staff has concluded that the following additional conditions of approval need to be added to the existing CoC[6] for the approval of this request:

- The maximum masses for the proposed Training Sources contents must be limited to the masses noted in Table A.1.1 of the Submittal;

- The Packaging Configuration requirements specified in Addendum Table A.1.2 of the Submittal, i.e., *Summary of Requirements*, must also be followed; and
- The Packaging Configuration requirements specified in Addendum Appendix 1.1 of the Submittal, i.e., *Configurations for Possible Shipments in 9977 Shipping Containers*, must be followed.

Chapter 8: Acceptance Tests and Maintenance Program

This section of the SER covers the review of the Acceptance Tests and Maintenance Program information provided in Chapter 8 of the Submittal.[1]

Details of the items reviewed are noted above in Chapter 1. The results of the acceptance tests and maintenance review are discussed below.

The addition of the Training Sources contents does not affect the Acceptance Testing of the packaging, nor does it affect the Maintenance Program requirements. Therefore, the package acceptance testing and basic maintenance program requirements, documented in the existing Model 9977-96 Package SARP, remain valid.

Findings

Based on the review of the statements and representations in the Submittal, the DOE PCP Staff has concluded that the packaging design has been adequately described to meet the operational requirements specified in 10 CFR 71.

Conditions of Approval

DOE PCP has concluded that no additional acceptance tests- or maintenance-related conditions of approval need to be added to the existing CoC for the approval of this request.

Chapter 9: Quality Assurance

This section of the SER covers the review of the Quality Assurance (QA) program description and packaging-specific QA requirements provided in Chapter 9 of the Submittal.[1]

Details of the items reviewed are noted above in Chapter 1. The results of the quality assurance review are discussed below.

The Submittal describes that the QA Program for the Model 9977 Packaging is documented in the SARP for the Model 9977 Packaging.[2] Chapter 9 of the Submittal contains a revised Q-list adding spacers, containers, and other dunnage. The DOE PCP Staff concurs that the addition of the Training Sources contents and associated spacers, containers, and other dunnage does not affect the QA program, as stated in Chapter 9 of the existing SARP, and that Chapter 9 of the existing SARP contains a reasonably up-to-date description of the applicant's QA program and packaging-specific QA requirements.

Findings

Based on review of the statements and representations in the Submittal, the DOE PCP Staff concludes that the QA program has been adequately described and meets the QA requirements of 10 CFR 71, Subpart H. Packaging-specific requirements are adequate to assure that the packaging is designed, fabricated, assembled, tested, used, maintained, modified, and repaired in a manner consistent with its evaluation.

Conditions of Approval

DOE PCP has concluded that no additional QA-related conditions of approval need to be added to the existing CoC for the approval of this request.

References

[1] *Model 9977, Safety Analysis Report For Packaging, Addendum 5, Justification for Training Sources Contents*, S-SARA-G-00009, Revision 2, Savannah River Packaging Technology, Savannah River National Laboratory, Aiken, South Carolina, May 2010.

[2] *Safety Analysis Report for Packaging, Model 9977, B(M)F-96*, S-SARP-G-00001, Revision 2, Savannah River Packaging Technology, Savannah River National Laboratory, Washington Savannah River Company, Savannah River Site, Aiken, SC (August 2007).

[3] *Safety Analysis Report for Packaging, Model 9977, Addendum, Justification for DNDO Contents*, S-SARA-G-00003, Revision 2, Savannah River Packaging Technology, Savannah River National Laboratory, Savannah River Nuclear Solutions, Savannah River Site, Aiken, SC (October 2008).

[4] *Safety Analysis Report for Packaging, Model 9977, Addendum, Justification for Metal Contents*, S-SARA-G-00005, Revision 1, Savannah River Packaging Technology, Savannah River National Laboratory, Savannah River Nuclear Solutions, Savannah River Site, Aiken, SC, December 16, 2008.

[5] *Safety Analysis Report for Packaging, Model 9977 Addendum 3, Justification for Small Gram Quantity Contents*, S-SARA-G-00006, Revision 4, March 2010.

[6] USA/9977/B(M)F-96 (DOE), *United States Department of Energy Certificate of Compliance for Radioactive Materials Packages, Model 9977*, Revision 4, United States Department of Energy, Washington, DC, expires October 31, 2012.

[7] USA/9977/B(M)F-96 (DOE-S/T-1), *United States Department of Energy Certificate of Compliance for Radioactive Materials Packages, Model 9977*, Revision 0, United States Department of Energy, Washington, DC, expires December 31, 2013.

[8] *Thermal Analysis of 9977 Package for Transport of Training Source Nuclear Materials, M-CLC-A 00385* Revision 0, Savannah River Packaging Technology, Savannah River National Laboratory, Savannah River Nuclear Solutions, Savannah River Site, Aiken, SC (March 2010).

[9] *AL-SX (H1616) Container Support: Out-gassing of Polyethylene and Polycarbonate Resins*, Sandia Report SAND99-8242, G.C. Story, et. al (1999).

[10] American National Standards Institute, *American National Standard for Radioactive Materials-Leakage Tests on Packages for Shipment*, ANSI N14.5-1997, New York, New York, 10036.

[11] ANSI/ANS-8.1-1998, *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors*.

[12] LA-10860-MS, *Critical Dimensions of Systems Containing ^{235}U, ^{239}Pu, and ^{233}U*, 1986 Revision, Los Alamos National Laboratory, New Mexico.