

**Safety Evaluation Report for the
Justification for Small Gram Quantity Contents
Safety Analysis Report for Packaging
Model 9977
Addendum 3
S-SARA-G-00006, Revision 2
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OVERVIEW

The Department of Energy (DOE) would like to facilitate the shipment of Advance Gas Reactor (AGR), AGR-1 fuel compacts, from Idaho National Laboratory's (INL's) Materials and Fuels Complex to Oak Ridge National Laboratory (ORNL). The AGR-1 fuel compacts are considered as Type 5 in the submittal, and the total radioactive material mass limit is 1 gram. A Shielded Container will be used for the Type 5 Contents, i.e., the Small Gram Quantity-Shielded Container 3 (SGQ-SC3), which is fabricated from tungsten, encapsulated in a stainless steel container with a threaded closure to provide photon shielding. This new content will be authorized for shipment in the Model 9977-96 Package, supplementing existing Revision 2 to the Safety Analysis Report for Packaging (SARP), once Addendum 3, *Justification for Small Gram Quantity (SGQ) Contents*, is accepted by the Headquarters 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 apparatus is the latest content added to the Model 9977-96 Package SARP.

Addendum 3 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 INL.

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

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

This Safety Evaluation Report (SER) addresses Type 5, fuel compacts only. Type 4 and Types 1–3 will be covered, respectively, in separate reviews. Hereafter, in this SER, Type 5 will be referred to as fuel compacts.

Chapter 1: General Information

This Safety Evaluation Report documents the DOE Packaging Certification Program (PCP) Staff's review of *Justification for Small Gram Quantity Contents, Safety Analysis Report for Packaging, Model 9977, Addendum 3, S-SARA-G-00006, Revision 2* (February 2010)^[1] (Submittal) prepared for the Department of Energy (DOE) by Savannah River Packaging Technology, Savannah River National Laboratory, Savannah River Nuclear Solutions, LLC, Savannah River Site, to support shipments by INL 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] just as S-SARA-G-00003, Revision 2^[3] is Addendum 1, *Justification for DNDO Contents*, to the Model 9977-96 Package SARP. Addendum 2 to the Model 9977-96 Package SARP is *Justification for Metal Contents*, S-SARA-G-00005, Revision 1, December 16, 2008.^[4] The safety basis, as described in the Submittal, addresses specific supplements to the currently approved SARP. The Model 9977-96 Package is currently certified for transport by the DOE under Revision 2 to the CoC.^[5]

The new Content Envelope, fuel compacts, will assist with shipment of AGR-1 fuel compacts from INL to ORNL. The fuel compacts are each limited to 1 gram of total radioactive materials and 5 grams of light elements and impurities, for a total content mass of 6 grams. Actinides, such as ^{242m}Am, ²⁴³Cm, ²⁴⁵Cm, ²⁴⁷Cm, ²⁴⁹Cf, and ²⁵¹Cf, are limited to a total of 1,000 parts per million (ppm). For the individual fuel compacts, each contains 0.804 grams of radioactive isotopes, each weighs approximately 5.5 grams, each has an activity of about 24 Ci, and each generates about 0.1 W.^[6,7] The fuel compacts have been irradiated for approximately 2.5 years in the Advanced Test Reactor as part of the AGR studies. The fuel compact is nominally 25 mm in length and 12.3 mm in diameter. Each compact contains about 4,200 coated fuel particles, each less than 1 mm in diameter. Each particle consists of a fuel kernel, composed of 75% UO₂, with the remainder as UC and/or UC₂, surrounded by, sequentially, a porous carbon buffer, an inner layer of pyrolytic carbon, a silicon carbide barrier coating, and an outer layer of pyrolytic carbon. Prior to irradiation, each fuel compact contained approximately 0.18 grams ²³⁵U in the form of 19.74 % enriched uranium.

A Shielded Container is proposed for use in transporting the irradiated fuel compact nuclear materials. The Shielded Container is constructed from tungsten, which is encapsulated in an external stainless steel container with a threaded stainless steel closure. The tungsten provides the gamma shielding, and is superior to lead in this respect. The tungsten Shielded Container (SGQ-SC3) will be used to meet the requirements specified in 10 CFR 71.47.^[8] The decay heat load is limited to 19 watts, as is standard for the Model 9977-96 Package.

The fuel compact will be placed in a small pipe container, consisting of a short threaded pipe section closed with end caps, with a closed length of at least 2.8 inches, such as that shown in Figure A.1.4 of the Submittal. The fuel compact will then be placed in the cavity of the tungsten Shielded Container; centering in the cavity will be provided by the pipe container. The Submittal addresses nonexclusive use shipments, and the maximum weight of the payload remains at 100 pounds.

Findings

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

Conditions of Approval

The DOE PCP Staff has concluded that the following conditions of approval need to be added to the existing CoC for the approval of this request. [Note: This review specifically excludes the Type 1, Type 2, Type 3, and Type 4 Contents of Table A.1.1 of the Submittal]:

- The fuel compact will be placed in a small pipe container, consisting of a short threaded pipe section closed with end caps, with a closed length of at least 2.8 inches, such as that shown in Figure A.1.4 of the Submittal. The fuel compact will then be placed in the cavity of the tungsten Shielded Container (i.e., the SGQ-SC3); centering in the cavity will be provided by the pipe container.
- The requirements specified for the Type 5 Contents, as specified in Addendum Table A.1.2, *SGQ Packaging Configuration*.

Chapter 2: Structural Evaluation

This section of the SER covers the review of the Structural Evaluation information provided in Chapter 2 of the Submittal.

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

The fuel compact SGQ Content Envelope addition does not exceed the total payload mass certified for shipment in the Model 9977 Package. The authorized maximum content weight and packaging configuration are the same as that evaluated in the Model 9977 Package SARP. Therefore, the packaging structural performance of the 6-inch Containment Vessel (6CV) and overpack, as documented in the Model 9977 Package SARP, is valid for the fuel compact SGQ Content Envelope addition. The structural performances of the SGQ-SC3 within the 6CV are evaluated, in detail, in Appendix 2.1, *Design and Evaluation of a Shielded Carrier for Use in 6 inch Containment Vessel of the 9977 Package*,^[9] of Addendum 3 to the Model 9977 Package SARP, and are shown to adequately meet the requirements of 10 CFR 71.

Findings

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

Conditions of Approval

The 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.

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.^[5] The maximum decay heat from radioactive contents is limited to 19 watts per package, which is based on the considerations of materials integrity for the 6CV, and the maximum operational temperature limit of the Viton[®] O-Rings.^[10]

The applicant has estimated that the maximum decay heat rate for the fuel compacts is more on the order of 0.1 watts per compact,^[7] which has been independently verified by the DOE PCP Staff. With a maximum of one (1) fuel compact allowed per package, the allowable contents are well within the bounds of the existing certification limits.

Findings

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

Conditions of Approval

The 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.

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 fuel compact SGQ Content to the Model 9977-96 Package SARP does not increase the impact loading on the containment vessels, the temperatures that must be sustained, nor the pressure that must be contained. Therefore, package containment *leaktight* performance (in accordance with ANSI Standard N-14.5^[11]), as documented in the existing Model 9977-96 Package SARP, is valid for the fuel compact Content Envelope addition.

Findings

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

Conditions of Approval

The 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.

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

Shielding Evaluation

This SER section covers the review of contents comprised of a single AGR-1 spent fuel compact. The applicant has provided external dose rates for the spent fuel compact placed inside the tungsten Shielded Container that is, in turn, placed inside the 6CV of the Model 9977-96 Package. The neutron and gamma source terms for the spent fuel were estimated using the isotopic composition of the fuel as provided by INL. Using independent calculations, the DOE PCP Staff has confirmed the applicant has adequately demonstrated that the external radiation levels meet the regulatory requirements for non-exclusive use shipments.

Findings

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

Conditions of Approval

The CoC will contain the restriction that the individual isotopic masses for the AGR-1 fuel compact are bounded by the isotopic limits specified in Table A.App.1.2.1, *Isotopic Composition of Individual AGR-1 Fuel Specimen (Compact)*, contained in Appendix 1.2 of the Submittal.

No additional shielding-related conditions of approval are required to be added to the existing CoC for the shipment of a single AGR-1 fuel compact.

Chapter 6: Criticality Evaluation

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

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

Criticality Evaluation

This SER section covers the shipment of a single AGR-1 spent fuel compact. The spent fuel compact has a fissile material content of less than 40 mg with an overall radioactive material content of approximately 800 mg. However, the applicant has provided calculations for 100 grams of fissile material per package, and shown that an infinite array of packages can be

shipped under both normal conditions of transport and hypothetical accident conditions with a total mass of 100 grams of fissile material per package, including all the isotopes listed in Table A.6.1, *Analyzed Content Envelopes*, of the Addendum. Thus, the AGR-1 spent fuel compact is bounded by these calculations, and the package with a single fuel compact can be shipped with a Criticality Safety Index (CSI) of 0.0. The DOE PCP Staff concurs with these evaluations.

Findings

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

Conditions of Approval

The new content, consisting of a single AGR-1 fuel compact in a Model 9977-96 Package, can be shipped with a CSI of 0.0. The DOE PCP has concluded that no additional criticality-related conditions of approval need to be added to the existing CoC for approval of the Submittal.

Chapter 7: Operating Procedures

This section of the SER covers the review of the Operating Procedures information provided in Chapter 7 of the Submittal.

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

The existing Model 9977 SARP provides the basic procedural steps for operating the Model 9977 Package for the previously accepted contents. For the newly proposed contents, i.e., the AGR-1 fuel compacts, the requirements specified in Section 1.2.2.2.2, and in Table A.1.2, of the Submittal, must also be followed, along with the specific procedures outlined in Steps 1, 2, 6, 8, and 12 of Section 7.1.1.2 of the Submittal.

Findings

In the format currently provided, the DOE PCP Staff has concluded that procedural steps provided for the loading of the AGR-1 fuel compacts should be revised to be more concise. The DOE PCP Staff has also concluded, however, that this can be performed in a more appropriate manner in the next revision to the Submittal, when a number of additional contents are expected.

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

Conditions of Approval

Because the requirements specified in the Operating Procedures Chapter of the SARP are normally incorporated, in their entirety, as Conditions of Approval in the CoC, the DOE PCP has concluded that, for the newly proposed contents, i.e., the AGR-1 fuel compacts, the requirements specified in Section 1.2.2.2.2, and in Table A.1.2, of the Submittal, 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 Submittal must be included as new Conditions of Approval in the CoC for the approval of this request.

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.

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 fuel compact as 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.

It should also be noted, that INL will be responsible for fabrication of the SGC-SC3, the tungsten Shielded Container, for the fuel compacts. Addendum Appendix 8.2, *Packaging Independent Verification Items*, Table A.App.8.2.1, *Dimensions/Materials Requiring Independent Verification Records*, lists four (4) dimensions that require independent verification for the SGQ-SC3. These numbered items (17–20) are identified on Drawing R-R1-G-00039, *Small Gram Quantity Shielded Container, Type 3*.

As is also noted by the applicant,

“The Small Gram Quantity Shielded Containers perform a function integral to the Package Safety performance and its compliance with the Code of Federal Regulations. As such, the Shielded Containers have required Quality (“Q”) dimensional inspections listed in Addendum Appendix 8.2, which are documented per SARP Table 9.7, with the documentation issued to the Design Authority for retention.”

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

The DOE PCP Staff has concluded that the following additional condition of approval needs to be added to the existing CoC for the approval of this request:

- The documentation packages for the Q items, numbered as 17–20, in Table A.App.8.2.1 must be supplied by the Site directing fabrication, to Savannah River National Laboratory as the Design Authority/Design Agency.

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.

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

The Submittal describes that the QA Program for the Model 9977-96 Packaging is documented in the *SARP for the Model 9977 Packaging*.^[2] Chapter 9 of the Submittal contains a revised Q-list adding the three Shielded Containers, two Spacers, and Cup. The DOE PCP Staff concurs that the addition of the Small Gram Quantity contents, Shielded Containers, Spacers, and Cup do 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 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

The 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] *Justification for Small Gram Quantity Contents, Safety Analysis Report for Packaging, Model 9977, Addendum 3, S-SARA-G-00006, Revision 2, Savannah River Packaging Technology, Savannah River National Laboratory, Savannah River Nuclear Solutions, Savannah River Site, Aiken, SC (February 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] USA/9977/B(M)F-96 (DOE), *United States Department of Energy Certificate of Compliance for Radioactive Materials Packages, Model 9977, Revision 2, United States Department of Energy, Washington, DC, expires October 31, 2012.*

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- [6] Statement of Work, *SRS Support Work to Obtain a Certified 9977 Shipping Package Configuration for Shipment of AGR-1 Compacts*, Idaho National Laboratory, Project No. 29412, SOW-7230, Revision ID: 0, April 6, 2009.
- [7] *Decay Heat Rate for AGR-1 Fuel Compacts*, G.A. Abramczyk, M-CLC-A-00383, Revision 0, February 3, 2010.
- [8] Nuclear Regulatory Commission, 10 CFR Part 71, *Compatibility with IAEA Transportation Standards (TS-R-1) and Other Transportation Safety Amendments*; Final Rule, 69 F.R. 3698, pp. 3698–3814, January 26, 2004, as amended.
- [9] *Design and Evaluation of a Shielded Carrier for Use in 6 Inch Containment Vessel of the 9977 Package*, C.A. McKeel, M-CLC-A-00371, Revision 1, December 17, 2009.
- [10] *Thermal Analysis of 9977 Package for Small Gram Quantity (SGQ) Transport of Nuclear Materials*, N.K. Gupta, M-COC-A-00368, Revision 1, October 30, 2009.
- [11] 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.