Safety Evaluation Report for SARP 9975 Addendum, Shipment of MOX in Plastic Bottles in Model 9975 Packaging, S-SARA-G-00015, Revision 3

Docket No. 13-29-9975

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SUMMARY

The National Nuclear Security Administration Office of Global Threat Reduction (NA-21) submitted a letter[1] with an Addendum[2] for the Safety Analysis Report for Packaging (SARP)[3] Model 9975 on June 20, 2013, requesting an amendment to the DOE Certificate of Compliance (CoC) USA/9975/B(M)F-96 (DOE), Revision 8, for shipping plutonium/uranium mixed oxide (MOX) packed in plastic bottles using the 9975 packaging.

Revision 8 of the CoC USA/9975/B(M)F-96 (DOE) was approved for the consolidated SARP for 9975-85 and 9975-96 packages. While the regulatory review of the consolidated SARP was underway, a higher priority need developed for shipments of MOX in plastic bottles. This need was addressed by Revision 2 Addendum to the SARP[3] and resulted in the issuance of DOE CoC 9975-96 Revision 7. However, shortly after the CoC Revision 7 was issued in April 2013, NA-21 notified DOE Packaging Certification Program (PCP) that the content/conditions shown in the Revision 7 CoC were not achievable for the shipments of plastic bottles in a foreign country. Several conference calls and a meeting were conducted and as a result, NA-21 submitted the Revision 3 Addendum[2] on June 21, 2013.

Several changes were made in the Revision 3 Addendum:
(1) the moisture level in the MOX content shall be established using calculations, measurements, or process history before loading;
(2) all void spaces inside the primary containment vessel (PCV) shall be inerted with nitrogen at the time of closure so that the oxygen concentration is below a selected value of either 1 vol.% or 2 vol.%;
(3) the shipping period shall be determined based on the established moisture level and initial oxygen concentration level, as shown in Table 1 below (reproduced from Table A.1.1 in the Revision 3 Addendum);
(4) the plastic bottles shall be placed inside a filtered stainless steel or tin-plated carbon steel can, and the filtered cans shall have the removal efficiency of greater than 99% for 5-micron or larger particulates; and
(5) a perforated stainless steel or tin-plated carbon steel can, shall be placed below the filtered can, as dunnage.

Table 1 – Shipping Period Based on Nitrogen Inerting, Moisture Level in MOX and Initial Oxygen Concentration [a, b, c]

Moisture in MOX (wt%)	Shipping Period (days)	
	1% initial O_2 (10,000 ppm)	2% initial O_2 (20,000ppm)
2.42	18	12
2.0	23	15
1.5	32	20
1.0	51	33
0.54	115	74
0.50	129	83

a) The shipping windows are derived from Table 1 with each of the shipping periods cut in half following NRC guidance. The Table 1 values are from X-CLC-A-00091, Revision 1.
b) Assumes Uranium is U_3O_8.
c) Limiting Oxygen Concentration (LOC) is 4.0% corresponding to a maximum PCV gas temperature of 313°F.

Transport Index (TI)
The TI is to be determined by measurement at the time of transport. The TI shall be less than 10 for nonexclusive use shipment per 10 CFR 71.47(a).

Criticality Safety Index (CSI)
On the basis of infinite array analyses performed in Section 6 of this Safety Evaluation Report (SER), the CSI is zero for the shipment of MOX in the plastic bottles in the Model 9975 Packaging.

On the basis of the statements and representations in the Revision 3 Addendum[2], and the DOE Packaging Certification Program (PCP) staff's confirmatory evaluation, as summarized in this SER, PCP finds that the design and performance of the 9975 package is acceptable for the shipment of MOX in plastic bottles and will provide reasonable assurance that the regulatory requirements of 49 CFR Part 173, 10 CFR Part 71, and DOE Order 460.1C have been met.

DOE PCP has also concluded that the following conditions of approval need to be added to the CoC Revision 10 pursuant to the approval of the application request, as follows:

1. *Addendum Conditions 1 and 2 in Chapter 1 on page 7 of 54 are not authorized for use.*

2. *Only 9975 packages certified as "-96" packages shall be used for these shipments.*

3. *The maximum amount of plastic materials in the PCV, including high-density polyethylene, low-density polyethylene, or polyvinyl chloride bottles, low-density polyethylene bagging, and polyvinyl chloride tape, shall be no more than 200 grams.*

4. *The plastic bottle shall be placed into a filtered stainless steel or tin-plated carbon steel can. The filtered can shall have a particle removal efficiency of greater than 99% for 5-micron or larger particulates. A perforated stainless steel or tin-plated carbon steel can shall be placed below the filtered can, as a dunnage.*

5. *Only one 1,000-mL plastic bottle can be loaded into a 9975 package. The maximum amount of* PuO_2 *shall be less than 240 grams in each 9975 package.*

6. *There must be free communication of gases between the PCV, the steel cans, the plastic bags, and the plastic bottle placed into the PCV.*

7. *At the time of closure of the PCV, all void spaces in the PCV, including the void spaces inside the steel cans, the plastic bottles and the plastic bags, shall be inerted with nitrogen so that the initial oxygen concentration is below a selected value of either 1 vol. % or 2 vol.%.*

8. *The shipping period of the 9975 package shall be determined on the basis of the moisture level in the MOX and the initial oxygen concentration, as shown in Table 1 of this SER. The shipping period is from the time of PCV closure to the time of delivery.*

9. *If an abnormality is detected during or after shipment and prior to or upon opening the PCV, or if the shipping period specified in Table 1 is violated, the package shall be placed in a secure area, and a non-conformance report shall be written, evaluated, and dispositioned. In addition, the regulatory agency having jurisdiction shall be notified.*

10. *When used outside of the United States, the applicable regulatory authority shall review and approve in writing the approval conditions 1 through 8 above.*

1. GENERAL INFORMATION AND DRAWINGS

Detailed packaging descriptions and drawings of the package can be found in the 9975 SARP.[3] The components of the 9975 packaging include a 35-gallon drum assembly, impact-limiting and thermal-insulating material Celotex, a Secondary Containment Vessel (SCV), a PCV, and the content containers. The 9975 packaging assembly is shown in Figure 1.1 and in Drawing R-R2-F-0026 of Appendix 1.1 of the SARP.

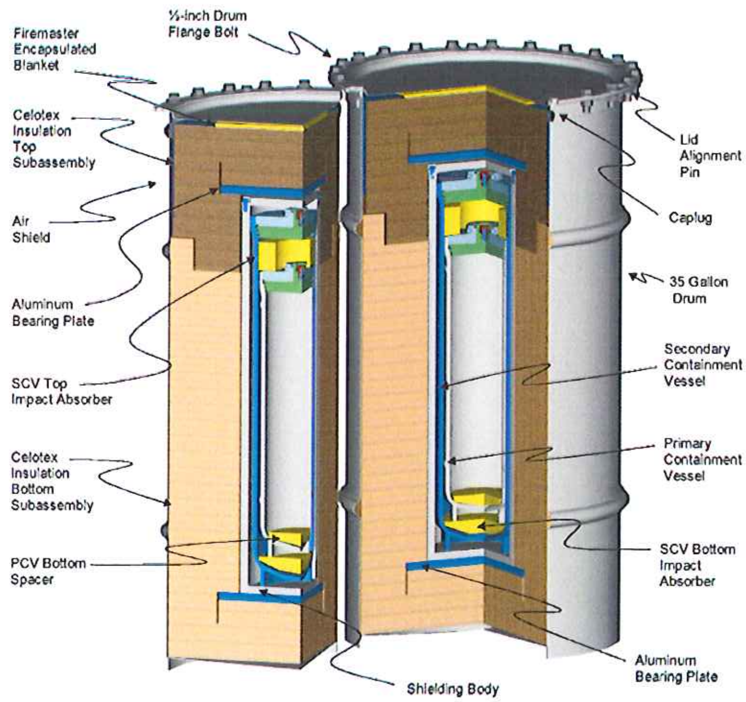

Figure 1.1 9975 Packaging 3-Dimensional Section View

The PCV is fitted with an aluminum sleeve to fill the space between food-pack cans and the inner wall of the PCV, as illustrated in Figure 1.5 of the SARP.[3] For configurations containing plastic bottles, the PCV sleeve is not analyzed in the gas generation calculation. The PCV sleeve is to restrict the radial run-up length to avoid the deflagration to detonation transition (DDT).[3] For the shipment of MOX in plastic bottles, there will be no DDT due to nitrogen inerting so the PCV sleeve will not be used for the shipments.

The content requested in the Addendum is in the form of MOX currently contained in 1,000-mL bottles, which were packed three decades ago in 1983.[4] The maximum 9975 package content loading for the plastic bottle configurations requested in the Addendum is 2,314 grams of MOX, with up to 410 grams of Plutonium as Pu-239 and 1,580 grams of Uranium as U-235. The radionuclide isotopic distribution is limited to that described in Table 1.2, Column C.4, in the baseline 9975 SARP. Non-radionuclide impurities are limited to those described in Table 1.2, Column C.4. Radionuclides not described in Table 1.2 of the SARP are limited to 1,000 ppm.

A typical plastic bottle configuration within the PCV for the MOX contents is shown in Figure 1.2 (this is Figure A.1.1 in the Revision 3 Addendum). The plastic bottle is placed into a filtered stainless steel or tin-plated carbon steel can. The filtered can shall have a particle removal efficiency of greater than 99% for 5-micron or larger particulates. In order to protect the plastic bottle and the filtered can, a perforated stainless or tin-plated carbon steel can shall be placed below the filtered can.

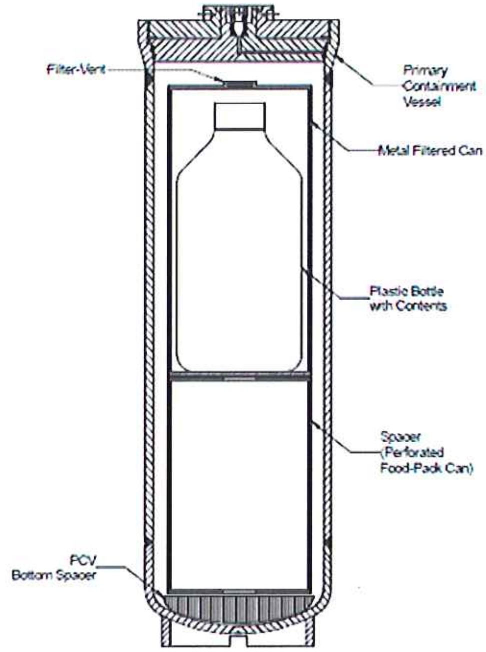

Figure 1.2 Typical plastic bottle configuration within the PCV for shipping MOX content

The Addendum lists three alternative conditions for controlling the generation of hydrogen during the shipment period and evaluates the use of the 9975 without the PCV Sleeve. Two of the conditions determine safe shipping periods of six (6) days (Condition 1) or forty five (45) days (Condition 2) by limiting the rates for gas generation. The third condition assumes the void spaces internal to the PCV are inerted with nitrogen prior to closure of the PCV. It is assumed that for all three conditions, there is no hydrogen in the plastic bottles at the time of loading. Given the uncertainties associated with the amount of moisture content, plastic hydrogenous material, and calculations of the shipping period, the DOE PCP staff concluded that inerting the PCV, the plastic bags, and the plastic bottle is a required condition to ensure safety of shipping the MOX in plastic bottles, which excludes Conditions 1 and 2 from this review. Condition 3 is acceptable only if all void space in the plastic bottle is inerted with nitrogen at the time of closure of the PCV, and that there is adequate communication between the void space of the plastic bottle and the plastic bags and the void spaces of the PCV (see Section 3 of this SER for additional details.)

On the basis of the statements and representations in the Addendum and the DOE PCP staff's confirmatory evaluation, PCP finds the general information (and drawings) presented in Chapter 1 of the Addendum acceptable for transport of MOX in plastic bottles and will provide reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

DOE PCP has also concluded that the following conditions of approval need to be added to the CoC, pursuant to the approval of the application request:

"Addendum Conditions 1 and 2 are not authorized for use."

"Only 9975 packages certified as "-96" packages shall be used for these shipments."

"The maximum amount of plastic materials in the PCV, including high-density polyethylene, low-density polyethylene, or polyvinyl chloride bottles, low-density polyethylene bagging, and polyvinyl chloride tape, shall be no more than 200 grams."

"The plastic bottle shall be placed into a filtered stainless steel or tin-plated carbon steel can. The filtered can shall have a particle removal efficiency of greater than 99% for 5-micron or larger particulates. A perforated stainless steel or tin-plated carbon steel can shall be placed below the filtered can, as a dunnage."

Evaluations of design and performance of the package for safety and regulatory compliance in structural, thermal, containment, shielding, criticality safety, operating procedures, acceptance tests and maintenance, and quality assurance are provided in the remaining sections of this SER.

2. STRUCTURAL

2.1 Discussion

DOE PCP staff reviewed the structural design and performance, as described in Chapter 2 of the 9975 SARP and Chapter 2 of the Addendum[2] for the shipment of MOX contained in plastic bottles. DOE PCP staff also reviewed the material compatibility between the MOX content, the plastic bottles, the perforated convenience can, and the PCV.

2.2 Structural Evaluation

For shipping MOX in plastic bottles, the maximum content weight, including the MOX, the plastic bottles, plastic bags, and the perforated spacer, is limited to 44.4 lb, which is the maximum payload weight of the 9975 package; therefore, the structural evaluation in the baseline 9975 SARP remains valid.

The MOX is contained in the plastic bottles. The integrity of the plastic bottles shall be assessed before they are loaded into the 9975 package, and there shall be no apparent degradation of the plastic bottles that are to be shipped, such that the plastic bottles will remain intact under normal conditions of transport. Therefore, the MOX content will not be in contact with the PCV, and there is no material incompatibility between the content, the plastic bottles, the stainless steel or tin-plated perforated and filtered cans, and the stainless-steel PCV.

2.3 Conclusion

On the basis of the statements and representations in the 9975 SARP Addendum and the DOE PCP staff's confirmatory evaluation, PCP finds that the structural design and performance presented in Chapter 2 of the Addendum are acceptable for transport of MOX in plastic bottles and will provide reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

3. THERMAL

3.1 Discussion

DOE PCP staff reviewed the thermal design and performance of the 9975 package for the shipment of MOX in plastic bottles, as described in Chapter 3 of the SARP, Chapter 3 of the Addendum and the calculation sheet X-CLC-A-00091, *Flammability Analysis for Mixed Actinide Oxide Packaged in 9975 Shipping Containers.* The review and evaluation were focused on the decay heat of the MOX contents, the nitrogen inerting, and the potential melting of the plastic bottles.

3.2 Thermal Evaluation

Decay Heat
The content requested to be shipped is 2.314 kg MOX, up to 410 grams of plutonium as Pu^{239} and 1,580 grams of uranium as U^{235}, with maximum alpha decay heat of 1.98 watts, as shown in the calculation sheet of X-CLC-A-00091; the total decay heat load calculated by staff is 3.5 watts. Both the content mass and the total decay heat are bounded by the 4.4 kg and the 19 W of content envelope C.4 approved for the 9975 packaging.[2]

Nitrogen Inerting
For nitrogen inerting, the Addendum states,

"*Condition 3: Both of the following must be met*

- *The PCV is inerted with nitrogen so that at the time of closure the oxygen content in all void spaces is no greater than 5% by volume.*

- *A calculation is performed showing that the gas generation rate of the content does not generate gases that will allow the PCV to exceed the Maximum Normal Operating Pressure as documented in the SARP.*

Condition 3 does not require a shipping window."

The above criteria are based on the assumption that there is no net oxygen generation during the shipment and the oxygen generated is fully absorbed via PuO_{2+x} (DOE-STD-3013-2004). However, the newly published standard, DOE-STD-3013-2012, and the reference J.M. Duffey and R.R. Livingston, *Gas Generation Testing of Plutonium Dioxide* (WSRC-MS-2002-00705, September 2002), provide evidence indicating that free oxygen can be generated and present in the gas phase. Although hydrogen/oxygen generation can be prevented when the system backpressure rises to a certain level (e.g., 25 psig for the fuel-grade Pu oxide; see Duffey and Livingston's paper cited above), one has to make sure that a flammable gas mixture has not been already generated before the system reaches the steady-state pressure.

Inerting all void spaces in the PCV with nitrogen, such that the oxygen concentration in all void spaces is below the Limiting Oxygen Concentration (LOC) in the hydrogen-air-nitrogen gas mixture, will eliminate the possibility of a flammable gas. At 25°C, the LOC in the hydrogen-air-nitrogen gas mixture is 4.3% by volume. However, it decreases with the increase in initial gas temperature. Given that the temperature in the plastic bottle is 103°C under Normal Conditions of Transport (NCT) (see Calculation Sheet X-CLC-A-00091, *Flammability Analysis for Mixed Actinide Oxide Packaged in 9975 Shipping Containers*), the void spaces in the PCV and the interior of the plastic bottles have to be inerted with a sufficient amount of nitrogen such that the oxygen concentration shall be less than the LOC of 3.9% by volume at 100°C (F. Van den Schoora, et al., *Flammability limits, limiting oxygen concentration and minimum inert gas/combustible ratio of $H_2/CO/N_2$/air mixtures,* International Journal of Hydrogen Energy, Volume 34, Issue 4, pages 2069–2075.).

DOE PCP staff conducted both the pressure and H_2/O_2 concentration calculations by assuming hydrogen generation rates of 1.65E-5 moles/h, which is considerably lower than 2.67E-5 moles/h stated in the Addendum. The PCP staff value was calculated on the basis of the bounding case of the L8 bottle[4] with the maximum amount of PuO_2 (235 g) and an apparent G-value of 0.03634 molecules/100eV (Calculation Sheet X-CLC-A-00091), the maximum moisture level of 2.42 wt.% in the MOX, and oxygen is generated stoichiometrically. The PCP staff results show that a flammable gas mixture would form before the system reaches the steady-state pressure. Therefore, a shipping period is required even when nitrogen inerting is used to ensure that there is no flammable gas mixture in any void spaces in the PCV. This shipping period is calculated conservatively by assuming:

1. An initial oxygen concentration of 100 ppm (See Chapter 7 of *Standard Glovebox Operating Instructions, Inertgas Technology*, MBRAUN GmbH, November, 2004.);
2. Free communication between the void space of the plastic bottle, plastic bags, and the void spaces of the PCV;
3. An LOC of 3.9% by volume; and
4. An oxygen generation rate of 7.63E-6 moles/h from radiolysis of moisture and adjusted to account for the 7.5% hydrogen generation from plastic.

The results show it would take 46 days to reach the LOC of 3.9% by volume. A shipping period of 23 days is recommended, taking into account of the uncertainties per NRC IN-84-72. If there is no free communication of gases between the void space of the plastic bottle and plastic bags, and the void spaces of the PCV, the calculated shipping period is no more than 5 days.

When an initial O_2 concentration of 100 ppm is not achievable, a higher initial O_2 concentration may be tolerated, with a corresponding shorter shipping period. The shipping period depends on the initial O_2 concentration and the moisture level in MOX. Table 3.1 below shows the shipping periods calculated under different moisture levels and initial O_2 concentrations of 1 or 2 vol.%.

Table 3.1 – Shipping Period Based on Nitrogen Inerting, Moisture Level in MOX and Initial Oxygen Concentration

Moisture (wt%)	Shipping Period [a, b, c] (days)		Shipping Period [a, b, d, e] (days)	
	Addendum[2]		DOE PCP Staff	
	1% initial O_2 (10,000 ppm)	2% initial O_2 (20,000ppm)	1% initial O_2 (10,000 ppm)	2% initial O_2 (20,000 ppm)
2.42	18	12	17	12
2.0	23	15	22	16
1.5	32	20	33	24
1.0	51	33	66	49
0.54	115	74	>115	>74
0.50	129	83	>129	>83

a) The shipping windows are derived from Table 1 (X-CLC-A-00091, Revision 1) with each of the shipping periods cut in half following NRC guidance.
b) Assumes Uranium is U_3O_8.
c) LOC is 4.0% corresponding to a maximum PCV gas temperature of 313°F.
d) LOC is 3.9% corresponding to a maximum PCV gas temperature of 313°F.
e) See Equation 14 in X-CLC-A-00091, Revision 1.

Potential Melting of Plastic Bottle

A plastic bottle typically has a relatively low allowable operating temperature limit. A low-density polyethylene bottle can be used continuously at 80°C (for short periods up to 95°C) and will melt around 120°C. No thermal property data for the plastic bottles are provided in the Addendum. A high gas temperature in the PCV may soften or melt the plastic bottles, creating challenges for content unloading.

In the calculation sheet X-CLC-A-00091 (page 35), the calculated averaged gas temperature within the PCV is 103°C, which exceeds the normal operating temperature of 80°C for low-density polyethylene plastic bottles. A stainless steel or tin-plated carbon steel can with a filter is used to contain the plastic bottle and improve handling and unloading safety.

3.3 Conclusion
On the basis of the statements and representations in the Addendum and the DOE PCP staff's confirmatory evaluation, PCP finds that the thermal design and performance presented in Chapter 3 of the Addendum are acceptable for ground transport of MOX in the plastic bottles and will provide reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

DOE PCP has concluded that the following conditions of approval need to be added to the CoC, pursuant to the approval of the application request:

"Only one 1,000-mL plastic bottle can be loaded into a 9975 package. The maximum amount of PuO_2 shall be less than 240 grams in each 9975 package."

"There must be free communication of gases between the PCV, the plastic bags, the steel cans, and the plastic bottle placed into the PCV."

"At the time of closure of the PCV, all void spaces in the PCV, including the void spaces inside the steel cans, the plastic bottles and the plastic bags, shall be inerted with nitrogen so that the initial oxygen concentration is below a selected value of either 1 vol. % or 2 vol.%."

"The shipping period of the 9975 package shall be determined on the basis of the moisture level in the MOX and the initial oxygen concentration, as shown in Table 1 of this SER. The shipping period is from the time of PCV closure to the time of delivery."

4. CONTAINMENT

4.1 Discussion
DOE PCP staff reviewed Chapter 4 of the Addendum and the SARP. The Addendum states that the proposed change in content configuration does not affect the description of the containment features of the Model 9975 B(M)F-96 package. DOE PCP staff concurs with this statement. The containment design and performance of the Model 9975 B(M)F-96 packages have been previously reviewed and approved.

4.2 Conclusion
On the basis of the statements and representations in the Addendum and the DOE PCP staff's confirmatory evaluation, PCP finds that the containment design and performance presented in Chapter 4 of the Addendum are acceptable for shipment of MOX in plastic bottles and will provide reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

5. SHIELDING

5.1 Discussion
DOE PCP staff reviewed Chapter 5 of the Addendum and the SARP for shipment of MOX in plastic bottles. The Addendum states, "*The plutonium/uranium oxide material identified in Chapter 1 consists of a mixture of uranium oxide and plutonium oxide with a mass of less than 2.3 kilograms. The plutonium/uranium oxide is bounded by the SARP Content Envelope C.4. Therefore no additional shielding analysis is required.*" DOE PCP staff concurs with this statement. The shielding design and performance of the base SARP have been previously reviewed and approved.

The TI is to be determined by measurement at the time of transport, and shall be less than 10 for nonexclusive use shipment per 10 CFR 71.47(a).

5.2 Conclusion

On the basis of the statements and representations in the Addendum and the DOE PCP staff's independent confirmatory evaluation, PCP finds that the shielding design and performance presented in Chapter 5 of the SARP are acceptable for shipment of MOX in plastic bottles and will provide reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

6. CRITICALITY

6.1 Discussion

DOE PCP staff reviewed the criticality safety design of the 9975 package described in Chapter 6 of the SARP and Chapter 6 of the Addendum for shipment of MOX in plastic bottles. DOE PCP staff also performed Monte Carlo analyses to independently confirm the criticality safety for a single package, as well as for an array of packages under the most reactive conditions during Normal Conditiona of Transport (NCT) and hypothetical accident conditions (HAC) for the requested MOX shipment.

6.2 Package Description

The 9975 package design includes two concentric stainless-steel containment vessels, a lead shielding body, aluminum bearing plates, cane and/or softwood fiberboard insulation, and aluminum impact absorbers inside a 35-gallon outer steel drum (see Figures 1.1–1.4 of the SARP). The payload is placed in convenience cans or bottles or otherwise protected to prevent contamination of the interior surface of the primary containment vessel. For the content covered by this Addendum, the payload is contained in plastic bottles.

Descriptions of the 9975 package design features include identification of (1) packaging materials and densities and compositions of packaging materials, and (2) the fissile/fissionable material forms, masses, and isotopic compositions of the payloads. The drawings included in the SARP provide the dimensions of the relevant packaging components. Chapter 2 of the SARP provides material specifications for the packaging components. DOE PCP staff confirmed that criticality-related information in the SARP is complete and representative of the actual materials specified for the 9975 package. PCP staff also confirmed that the models used in the criticality calculations are consistent with the drawings and the detailed package description given in the SARP.

Contents

Table 1.2 of the SARP lists 11 general content envelopes authorized for shipment in the 9975 package. The specific content covered by the Addendum and this SER is MOX, which will be shipped in plastic bottles. The plastic bottles have an outer lead sheath. Table 6.1 of the Addendum lists the characteristics of this MOX. The MOX in the plastic bottles is evaluated with respect to criticality safety in Chapter 6 of the Addendum.

6.3 Criticality Models

The KENO-VI code was used in the Addendum for criticality analyses. The payload and the neutronically significant components of the 9975 package were included in the KENO-VI models for shipment of the MOX in plastic bottles. Separate models were developed for single-package, NCT, and HAC analyses. The NCT and HAC array calculations for shipment of the MOX were based on detailed models of the 9975 package and on infinite arrays.

The Standard Composition Library and the 238GROUPNDF5 nuclear data library in the SCALE code package were used for all KENO-VI calculations in the Addendum and in the confirmatory analyses.

Section 6.8 of the Addendum summarizes the determination of the minimum k_{safe} value. The lowest k_{safe} value determined from the validation for the proposed MOX contents is 0.935. Therefore, any configurations of 9975 packages containing MOX in plastic bottles with $k_{eff} + 2\sigma < k_{safe}$ are deemed subcritical. All calculations incorporated sufficient neutron histories to ensure statistical uncertainty (σ) less than 0.002 and adequate convergence. DOE PCP staff concurs that the benchmark experiments and corresponding bias value are applicable and conservative as applied to the 9975 package with the contents covered by the Addendum.

6.4 Summary of SARP Addendum Criticality Analysis and Staff's Confirmatory Evaluation

Evaluation of a single package under NCT and HAC

The analyses in Section 6.4 of the Addendum consider configurations with intact plastic bottles and configurations with plastic bottles melted by the heat of the HAC fire. Two parametric studies were performed for the Addendum. In the first study, the plastic bottles remained intact and various portions of the packaging were flooded. In the second study, the SCV and insulation were flooded and the PCV was flooded to varying degrees. The plastic and MOX were mixed with the water in the PCV.

Table 6.1 below shows the maximum $k_{eff} + 2\sigma$ reactivity results listed in Section 6.4 of the Addendum and the DOE PCP staff's confirmatory analyses for the 9975 single-package configuration with two plastic bottles containing MOX. All single-package configurations resulted in acceptable $k_{eff} + 2\sigma$ values that are below the k_{safe} limit of 0.935. Therefore, the 9975 single package with the proposed MOX payload in plastic bottles is subcritical and satisfies the requirements of 10 CFR 71.55(b) related to a flooded single package.

Evaluation of undamaged package arrays (NCT)

The NCT undamaged package array model for shipment of MOX in plastic bottles consisted of an infinite array of 9975 packages. Each package contained two plastic bottles. There was no interstitial water between drums because interstitial water reduces the interaction between drums and, consequently, k_{eff} for the array (see Section 6.3.1 of the Addendum).

Table 6.1 shows the maximum $k_{eff} + 2\sigma$ reactivity results listed in the SARP Addendum and the DOE PCP staff's confirmatory analyses for shipment of MOX in plastic bottles under NCT. All NCT arrays resulted in acceptable $k_{eff} + 2\sigma$ values that are below the k_{safe} limit of 0.935. Therefore, the 9975 package with the proposed MOX payload in plastic bottles is subcritical and satisfies the requirements of 10 CFR 71.55(d) and 10 CFR 71.59(a)(1).

Evaluation of damaged package arrays (HAC)

The HAC damaged package array model for the MOX in plastic bottles consisted of an infinite array of packages. The package geometry and dimensions in the HAC model were modified to account for insulation loss and package deformation based on burn test and drop test data and to account for possible off-center positions of package components due to insulation loss in the fire.

Table 6.1 shows the maximum $k_{eff} + 2\sigma$ reactivity results listed in the SARP Addendum and the DOE PCP staff's confirmatory analyses for shipment of MOX in plastic bottles under HAC. All HAC arrays resulted in acceptable $k_{eff} + 2\sigma$ values that are below the k_{safe} limit of 0.935. Therefore, the 9975 package with the proposed MOX payload in plastic bottles is subcritical and satisfies the requirements of 10 CFR 71.55(e) and the HAC-related requirements of 10 CFR 71.59(a)(2).

Table 6.1 Summary of SARP and DOE PCP Staff Confirmatory Analyses for the 9975 Package with Mixed Oxide in Plastic Bottles

Case	Content	SARP Case	Maximum $k_{eff} + 2\sigma^a$	
			SARP	Staff
		Single Package		
S1	MOX	su_eurex_fld	0.299	0.29934
S2	MOX	su_solution_b3000	0.585	0.58267
		NCT Array		
N1	MOX	nct_eurex	0.292	0.29471
		HAC Array		
H1	MOX	hac_eurex_infctr	0.437	0.44225

a) Upper subcritical limit k_{safe} value is 0.935.

6.5 CSI for Nuclear Criticality Control

On the basis of NCT/HAC infinite array analyses of the shipment of MOX in plastic bottles in the 9975, a minimum CSI of 0.0 was determined and reported in Section 6.1.3 of the Addendum. DOE PCP staff concurs that this CSI value is appropriate for the 9975 package with the MOX content in plastic bottles.

6.6 Conclusion

On the basis of the statements and representations in the Addendum and the DOE PCP staff's confirmatory evaluation, PCP finds that the criticality safety design and performance presented in Chapter 6 of the Addendum are acceptable for shipment of MOX in plastic bottles and will provide reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

7. PACKAGE OPERATIONS

7.1 Discussion

DOE PCP staff reviewed the requirements for general operating procedures for loading, unloading, shipping, and receiving the Model 9975 packages and Addendum for shipment of MOX in plastic bottles; preparation of these empty Model 9975 packages for transport; and other operations, as described in Chapter 7 of the SARP and Addendum. The specific operational criteria for the package are presented in Chapter 7 and the Addendum, and shall be implemented by the package user. Each user of the 9975 packaging shall register with either the DOE PCP Manager or the applicable Competent Authority prior to the first use of the package.

7.2 Conclusion

On the basis of the statements and representations in the Addendum and the SARP and the DOE PCP staff's confirmatory evaluation, PCP finds that the operation procedures presented in Chapter 7 of the Addendum and the SARP acceptable for shipment of MOX in plastic bottles and will provide reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

DOE PCP has also concluded that the following condition of approval needs to be added to the CoC, pursuant to the approval of the application request:

"If an abnormality is detected during or after shipment, and prior to or upon opening the PCV, or the shipping period specified in Table 1 is violated, the package shall be placed in a secure area, and a non-conformance report shall be written, evaluated, and dispositioned. In addition, the applicable Competent Authority shall be notified."

8. ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Discussion

DOE PCP staff reviewed the requirements for Acceptance Tests and Maintenance that are in Chapter 8 of the 9975 SARP and Addendum. There is no change required in Chapter 8 of the SARP or the Addendum for the shipment of MOX in plastic bottles.

8.2 Conclusion

On the basis of the statements and representations in the Addendum and the SARP and the DOE PCP staff's confirmatory evaluation, PCP staff finds that the acceptance tests and maintenance program presented in Chapter 8 of the Addendum and the SARP are acceptable for shipment of MOX in plastic bottles and will provide reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

9. QUALITY ASSURANCE

9.1 Discussion

DOE PCP staff reviewed the requirements for the quality assurance program that are in Chapter 9 of the 9975 SARP and Addendum. There is no change required in Chapter 9 of the SARP or the Addendum for the shipment of MOX in plastic bottles.

9.2 Conclusion

On the basis of the statements and representations in the Addendum and the SARP and the DOE PCP staff's confirmatory evaluation, PCP finds that the quality assurance program presented in Chapter 9 of the Addendum and the SARP acceptable for shipment of MOX in plastic bottles and will provide reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

References

1. Letter from Sarah L. Dickerson, director of FSU and Asian Threat Reduction, Office of Global Threat Reduction (NA-21) of National Nuclear Security Administration (NNSA), to Dr. James M. Shuler, manager of Packaging Certification Program (PCP), Office of Packaging and Transportation (EM-33) of Department of Energy, "*Transmittal of Addendum Report 'Shipment of Plutonium/Uranium Mixed Oxide in Plastic Bottles',*" June 21, 2013.

2. Safety Analysis Report for Packaging Model 9975 Addendum, "*Shipment of Plutonium/Uranium Mixed Oxide in Plastic Bottles,*" S-SARA-G-00015, Revision 3, June 13, 2013.

3. Safety Analysis Report for Packaging Model 9975, S-SARP-G-00003, Revision 0, January 2008.

4. M. Harris and S.J. Nathan, Nuclear Criticality Safety Evaluation: 9975 Shipping Package Analysis with EUREX MOX Contents for SARP Addendum (U), N-NCS-A-00028, Revision 0, October 2012.