Department of Energy
Washington, DC 20585

OCT 26 2006

71-9315

ATTN: Document Control Desk,
Director, Spent Fuel Project Office
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Document Control Desk:

Request for Additional Information (RAI) for Amendment #1 of the ES-3100 Certificate of Compliance (CoC) were received by the U.S. Department of Energy on September 19, 2006. The RA1 responses for Amendment #1 of CoC No. 9315, Model ES-3100 Shipping Package, Docket No. 71-9315, TAC No. L23973, and a copy of this letter, will be sent by express mail directly to Kimberly J. Hardin, Project Manager, from BWXT Y-12. The responses are compiled in the document Y/LF-772. This response will include changed pages to the ES-3100 license application, specifically, Safety Analysis Report, Y-12 National Security Complex, Model ES-3100 Package with Bulk HEU Contents, Y/LF-717, Rev. 0. The Safety Analysis Report changes reflect the incorporation of specific wording modifications as described in the RA1 responses.

If you have any questions, please contact me at 301-903-5513 or Jeff Arbital at (865) 576-8254.

Sincerely,

James M. Shuler

James M. Shuler
Manage, Packaging Certification Program
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cc:
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BWXT Y-12

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Y/LF-772

Y-12 NATIONAL SECURITY COMPLEX

REQUEST FOR ADDITIONAL INFORMATION

CoC Revision 1

Docket No. 71-9315
TAC No. L23818

CoC No. 9315
Model ES-3100 Shipping Package

BWXT Y-12, L.L.C.

October 25, 2006

MANAGED BY
BWXT Y-12, L.L.C.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

UCN-13672 (10-00)

Y/LF-772

REQUEST FOR ADDITIONAL INFORMATION

CoC REVISION 1

CoC No. 9315
Model ES-3100 Shipping Package

October 25, 2006

Prepared by the
Y-12 National Security Complex
Oak Ridge, Tennessee 37831

Managed by
BWXT Y-12, L.L.C.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

Chapter 1 General Description

1-1 Clarify the statement on SAR p. 1-11: "These materials are essentially inert from the standpoint of criticality safety and chemical interaction with the ES-3100 convenience cans."

No similar statement is provided for the polyethylene bottles and the nickel-alloy can. Clarify this statement for the polyethylene bottle and the nickel-alloy can in the SAR.

This information is necessary to ensure compliance with 10 CFR 71.43(d).

Applicant Response:

The statement refers to all cans (steel and nickel) and all polyethylene bottles. For clarification, the subject statement on SAR page 1-11 will be revised to read as follows: "These materials are essentially inert from the standpoint of criticality safety and chemical interaction with all the ES-3100 convenience cans and bottles identified in this section for the shipment of HEU oxides."

Revised SAR page 1-11 is attached.

Chapter 3 Thermal

3-1 Justify the V_{bo} listed in Table 4 on SAR p. 3-151 and Table 4 on SAR p. 3-158 for CVA 6 (three 4.94 in. OD polyethylene bottles).

The discussion in the associated text provides a justification for the assumption that no off-gassing of the polyethylene bags and silicone rubber can pads will occur during normal and hypothetical accident conditions; however, the SAR text does not discuss the assumed amount of off-gassing of the polyethylene bottles. Justify this assumed amount of off-gassing in the SAR.

This information is necessary to ensure compliance with 10 CFR 71.43(d).

Applicant Response:

This question was discussed during a conference call on October 11, 2006. From the conference call, BWXT Y-12 had a clear understanding of the question and a proposed solution. There is no off-gassing of the silicone rubber pads or polyethylene bags and bottles at the NCT temperatures as indicated by V_{bo} and V_{po} being equal to 0 (SAR page 3-151). There is off-gassing of the silicone rubber pads and polyethylene bags and bottles at the HAC temperatures as indicated by V_{bo} and V_{po} being greater than 0 (SAR pages 3-157 and 3-158).

For clarification, word changes will be made on pages 3-150 and 3-157 of the SAR.

On page 3-150, the second paragraph under Section II, "**Molar quantity determination due to off-gassing for each containment vessel arrangement**" will be revised to read as follows:

"Using the above calculated results and the specific gas generation of polyethylene bags and silicone rubber pad measurements at temperatures up to 338 °F conducted by the Y-12

Development Division, the amount of gas (V_{bo} and V_{po}) generated due to off-gassing of the polyethylene bags and bottles, and silicone rubber can pads at any temperature is estimated by first determining the off-gassing volume per unit mass at temperature and multiplying that by the total mass of the bags and bottles, and silicone rubber can supports inside the containment vessel. Based on testing at a temperature of 93.33 °C (200 °F), no recordable off-gassing occurred in the polyethylene bags, or silicone rubber pad material as documented in Y/DZ-2585, rev. 2 (Appendix 2.10.4). This value was used to determine the off-gassing volume as shown below:

V_{po} = $W_p \times 0.0 / 16.387$ (in.^{3}) (off-gassing volume of silicone rubber pads)

V_{bo} = $W_b \times 0.0 / 16.387$ (in.^{3}) (off-gassing volume of polyethylene bags and bottles)"

On page 3-157, the second paragraph under Section II, "**Molar quantity determination due to off-gassing for each containment vessel arrangement**" will be revised to read as follows:

"Using the above calculated results and the specific gas generation of polyethylene bags and silicone rubber pads measurements at temperatures up to 338 °F conducted by the Y-12 Development Division (Appendix 2.10.4), the amount of gas generated due to off-gassing of the silicone rubber can pads, and the polyethylene bags and bottles at 123.85 °C (254.93 °F), (V_{po} and V_{bo}) is estimated by first determining the off-gassing volume per unit mass at temperature and multiplying that by the total mass of the bags and bottles, and silicone rubber can supports inside the containment vessel. Based on testing at an approximate temperature of 141.11 °C (286.00 °F), values of ~7.0 and ~0.8 cm^3 (STP)/g for the polyethylene bagging and bottles, and silicone rubber pads, respectively, were taken from the curves for the off-gassing volume per unit mass as documented in Y/DZ-2585, rev.2 (Appendix 2.10.4). These values are used to determine the off-gassing volume as shown below:

V_{po} = $W_p \times 0.8 / 16.387$ (in.^{3}) (off-gassing volume of silicone rubber pads)

V_{bo} = $W_b \times 7.0 / 16.387$ (in.^{3}) (off-gassing volume of polyethylene bags and bottles)"

Revised SAR pages 3-150, and 3-157 are attached.

Chapter 4 Containment

4-1 Correct the typos in the 4th paragraph of SAR p. 4-6 and in the 1st paragraph of SAR p. 4-10: in both cases, "nees" should read "needs."

This correction is necessary to satisfy the requirements of 10 CFR 71.7.

Applicant Response:

Typos on pages 4-6 and 4-10 of the SAR have been corrected as indicated by the reviewer.

Revised SAR pages 4-6 and 4-10 are attached.

ATTACHMENTS

SAR Page Changes

Group 2 oxides are in the form of UO_x. Material from this group contains at least 20.0% uranium by weight and displays typical isotopic content (≤0.977 g ^{235}U/g U, ≤0.014 g ^{234}U/g U, ≤0.010 g ^{236}U/g U, ≤0.040 μg ^{232}U/g U, ≤50.0 μg ^{233}U/g U with the balance of the uranium being ^{238}U).

Group 3 oxides are contaminated with up to 40 μg Pu/g U and are in the form of UO_x. Material from this group contains at least 83.0% uranium by weight and displays typical isotopic content for uranium (≤0.977 g ^{235}U/g U, ≤0.014 g ^{234}U/g U, ≤0.010 g ^{236}U/g U, ≤0.040 μg ^{232}U/g U, ≤50.0 μg ^{233}U/g U with the balance of the uranium being ^{238}U).

Group 4 oxides are in the form of U_3O_8. Material from this group contains at least 83.0% uranium by weight and displays typical isotopic content (≤0.977 g ^{235}U/g U, ≤0.014 g ^{234}U/g U, ≤0.010 g ^{236}U/g U, ≤0.040 μg ^{232}U/g U, ≤50.0 μg ^{233}U/g U with the balance of the uranium being ^{238}U).

Group 5 oxides are in the form of UO_x. Material from this group contains at least 20.0% uranium by weight and displays typical isotopic content (≤0.977 g ^{235}U/g U, ≤0.014 g ^{234}U/g U, ≤0.010 g ^{236}U/g U, ≤0.040 μg ^{232}U/g U, ≤50.0 μg ^{233}U/g U with the balance of the uranium being ^{238}U). This material may contain considerable activity in the form of unspecified beta emitters.

Group 6 oxides are in the form of UO_x. Material from this group contains at least 20.0% uranium by weight and may display unusually high isotopic concentrations of ^{233}U, ^{234}U, and ^{236}U (≤0.977 g ^{235}U/g U, ≤0.020 g ^{234}U/g U, ≤0.40 g ^{236}U/g U, ≤0.040 μg ^{232}U/g U, ≤200.0 μg ^{233}U/g U with the balance of the uranium being ^{238}U).

The oxides in Groups 1, 3, and 4 are high purity uranium oxide purity (the remainder is only trace impurities). Oxide Groups 2, 5, and 6 are listed to contain at least 20% uranium by weight, which allows up to 80% non-uranium material. As oxides, depending on the purity and chemical form, 3% to 17% of the total material composition will be oxygen, leaving up to 77% impurity or "filler". These three oxide groups include a range of scrap and recovered materials. For the least pure uranium oxides, the majority of the filler material is aluminum oxide (from recovered alumina traps or from oxidized uranium-aluminum alloys). Other materials that occur in appreciable quantities in some scrap materials are oxides and compounds of Boron, Calcium, Iron, Sodium, Lead, Zinc, Magnesium, Copper, Molybdenum, and Tungsten. These materials are essentially inert from the standpoint of criticality safety and chemical interaction with all the ES-3100 convenience cans and bottles identified in this section for the shipment of HEU oxides.

HEU Metal and Alloy

HEU metal and alloy may be in the form of solid geometric shapes. Solid shapes may include the following:

1. spheres having a diameter no larger than 3.24 in. (maximum of two spheres per convenience can);
2. cylinders having a diameter no larger than 3.24 in. (maximum of one cylinder per convenience can);
3. square bars having a cross section no larger than 2.29 in. × 2.29 in. (maximum of one bar per convenience can); and
4. slugs having dimensions of 1.5 in. diameter × 2 in. tall (maximum of 10 per convenience can).

HEU bulk metal and alloy contents not covered by the geometric shapes category specified above will be in the broken metal category, and will be so limited.

HEU bulk metal and alloy contents in the broken metal category may be of unspecified geometric form. HEU bulk metal and alloy in this category may also be of a specific shape where one or more of the characteristic dimensions vary from piece to piece (i.e., the height, width, length, radius, etc.). For pyrophoric considerations, HEU metal and alloy shipped in the ES-3100 must meet the following restrictions:

1. Pyrophoric forms, such as uranium metal powders, foils, turnings and wires shall not be shipped, unless the materials pass the following broken metal size restriction tests. Broken metal pieces should be of a size that: a) the specific surface area does not exceed 50 cm^2/g, and b) will not pass freely through a mesh size 8 sieve (2.38 mm or 0.0937 in). Other tests to determine pyrophoricity of the uranium metal contents may be used at the shipper's discretion and are subject to approval by the regulatory authority.

2. Incidental small particles and samples (those which do not pass the size restriction tests in #1) including foils, turnings, or wires may be shipped with the original batch, but are restricted to < 1% by weight of the content batch.

~~Metal may be shipped in tinned-carbon steel, stainless steel, or nickel-alloy convenience cans~~.

Uranyl Nitrate Crystals

Uranyl nitrate crystals (UNX) are formed by dissolving uranium metal or any of the uranium oxides in nitric acid. Uranyl nitrate hexahydrate (UNH) has a chemical formula of $UO_2(NO_3)_2 + 6\ H_2O$. This most reactive form is used as the bounding composition for uranyl nitrate crystals in the criticality evaluation. Therefore, for UNX contents, X must be less than or equal to 6. The theoretical density of UNH crystals is 2.79 g/cm^3; however, the working densities will be less.

The user of the ES-3100 for UNX shipments will be required to use non-metallic containers only (such as Teflon or polyethylene bottles) as the convenience container. ~~These types of convenience containers are not covered in this SAR.~~

1.2.3.1 Radioactive/fissile constituents

Fissile material mass loading limits for the contents of the ES-3100, as determined by criticality analyses, are presented in Table 1.3. For the ES-3100 package with bulk HEU content, the maximum number of A_2s is 290.37 (at 70 years) and the maximum activity is 0.3112 Tbq (at 10 years) [Table 4.4].

1.2.3.2 Chemical and physical form

The fissile material contents are in solid (HEU metal or alloy), crystalline (UNX) or powder (HEU oxide) form. Some moisture (up to 3%) may be present in the HEU oxide material, thereby making the oxide content clump together.

1.2.3.3 Reflectors, absorbers, and moderators

The reflectors, absorbers, and moderators present in the ES-3100 package are those associated with the materials of construction. For example, the thermal insulation acts as a neutron reflector to the contents of a single package and as a neutron moderator in an array of packages. The degree of neutron moderation is a function of the hydrogen content in the Kaolite 1600 and Cat 277-4 materials. The stainless-steel materials of the containment vessel and the drum also act as neutron reflectors to the contents of a single package but act as neutron absorbers in an array of packages. The nuclear properties of the materials of construction and of the contents are important and have been taken into account in the criticality safety

Table 1. Containment vessel void volume for each CVA

CVA		V_{ECV} (in.^{3})	V_{SP} [a] (in.^{3})	V_{PB} (in.^{3})	V_{CC} (in.^{3})	V_{CS} (in.^{3})	V_{CH} (in.^{3})	V_V (in.^{3})
1	Six 4.875-in.-high cans Seven silicone pads Six can handles	637.18	9.35	30.51	380.47	0.00	1.02	215.83
2	Five 4.875-high cans Nine silicone pads Three Cat 277-4 spacers Eight can handles	637.18	12.03	30.51	317.06	60.60	1.36	215.62
3	Three 8.75-in.- high cans Two Cat 277-4 spacers Six silicone pads Five can handles	637.18	8.02	30.51	345.96	40.40	0.85	211.44
4	Three 10-in.-high cans Four silicone pads Three can handles	637.18	5.35	30.51	396.20	0.00	0.51	204.62
5	Three 10-in.-high cans with can diameters of 5 in.	637.18	0.00	0.00	589.05	0.00	1.02	47.11
6	Three 4.94 in. OD polyethylene bottles	637.18	0.00	9.46	465.33	0.00	0.00	162.39

[a] These volumes are calculated from the weights shown on the engineering drawings and nominal material densities.

Using the above molar equations, the number of moles for water vapor and dry air in the vessel for each CVA is summarized in Table 2.

Table 2. Water vapor and dry air molar summary for each CVA

CVA	P_a (psia)	P_v (psia)	V_V (in.^{3})	R_u (ft-lb/lb-mole·R)	T_{amb} (R)	n_v (lb-mole)	n_a (lb-mole)
1	14.24	0.464	215.83	1545.32	537	1.0057e-05	3.0855e-04
2	14.24	0.464	215.63	1545.32	537	1.0047e-05	3.0826e-04
3	14.24	0.464	211.44	1545.32	537	9.8522e-06	3.0227e-04
4	14.24	0.464	204.62	1545.32	537	9.5344e-06	2.9252e-04
5	14.24	0.464	47.11	1545.32	537	2.1951e-06	6.7348e-05
6	14.24	0.464	162.39	1545.32	537	7.5666e-06	2.3215e-04

II. Molar quantity determination due to off-gassing for each containment vessel arrangement

The maximum temperature calculated for the containment vessel is 87.81°C (190.06°F). This temperature is assumed to be constant throughout the containment vessel and contents. Therefore, the polyethylene bags and silicone rubber can pads are assumed to be at this temperature.

Using the above calculated results and the specific gas generation of polyethylene bags and silicone rubber pad measurements at temperatures up to 338°F conducted by the Y-12 Development Division, the amount of gas (V_{bo} and V_{po}) generated due to off-gassing of the polyethylene bags and bottles, and silicone rubber can pads at any temperature is estimated by first determining the off-gassing volume per unit mass at temperature and multiplying that by the total mass of the bags and can supports inside the containment vessel. Based on testing at a temperature of 93.33°C (200°F), no recordable off-gassing occurred in the polyethylene bags or silicone rubber pad material as documented in Y/DZ-2585, rev. 2 (Appendix 2.10.4). This value was used to determine the off-gassing volume as shown below:

$$V_{po} = W_p \times 0.0 / 16.387 \text{ (in.}^3\text{)}$$ (off-gassing volume of silicone rubber pads)

$$V_{bo} = W_b \times 0.0 / 16.387 \text{ (in.}^3\text{)}$$ (off-gassing volume of polyethylene bags and bottles)

From the ideal gas law, the number of gas moles in the volume at standard temperature and pressure is as follows:

$$n_{io} = \frac{P_v \cdot V_i}{R_u \cdot T_{amb} \cdot 12}$$

A summary of the results obtained using the above equations for each containment vessel arrangement is presented in Tables 3 and 4.

Table 3. Molar quantity of gas generated due to the silicone rubber pad off-gassing

CVA	W_p (g)	V_{po} (in.^{3})	P_V (psia)	R_u (ft-lb/lb-mole·R)	T_{amb} (R)	n_{po} (lb-mole)
1	186.74	0.00	14.7	1545.32	537	0.0000e+00
2	240.09	0.00	14.7	1545.32	537	0.0000e+00
3	160.06	0.00	14.7	1545.32	537	0.0000e+00
4	106.71	0.00	14.7	1545.32	537	0.0000e+00
5	0.00	0.00	14.7	1545.32	537	0.0000e+00
6	0.00	0.00	14.7	1545.32	537	0.0000e+00

temperature recorded on the containment vessel wall and convenience can [92.78°C (199°F)], the average temperature of gas in this region is 92.78°C (199°F). Using the temperature adjustment of 27.89°C (50.20°F) for this region, the adjusted average temperature in the second region is 120.67°C (249.20°F). The third and final volume is represented by the gas adjacent to the bottom convenience can. Again, based on the convenience can temperature [87.78°C (190°F)] and the containment vessel end cap temperature [98.89°C (210°F), the average temperature of gas in this region is 93.33°C (200°F). Using the temperature adjustment of 24.94°C (44.90°F) for this region, the adjusted average temperature in the third region is 118.28°C (244.90°F). Averaging these three temperatures, an average adjusted gas temperature of 123.85°C (254.93°F) is determined for the containment vessel.

Using the above calculated results and the specific gas generation of polyethylene bags and silicone rubber pads measurements at temperatures up to 338°F conducted by the Y-12 Development Division (Appendix 2.10.4), the amount of gas generated due to off-gassing of the silicone rubber can pads, and the polyethylene bags and bottles at 123.85°C (254.93°F), (V_{po} and V_{bo}) is estimated by first determining the off-gassing volume per unit mass at temperature and multiplying that by the total mass of the bags and silicone rubber can supports inside the containment vessel. Based on testing at an approximate temperature of 141.11°C (286.00°F), values of ~7.0 and ~0.8 cm^3 (STP)/g for the polyethylene bagging and silicone rubber pads, respectively, were taken from the curves for the off-gassing volume per unit mass as documented in Y/DZ-2585, rev. 2 (Appendix 2.10.4). These values are used to determine the off-gassing volume as shown below:

$$V_{po} = W_p \times 0.8 / 16.387 \text{ (in.}^3\text{)}$$ (off-gassing volume of silicone rubber pads)

$$V_{bo} = W_b \times 7.0 / 16.387 \text{ (in.}^3\text{)}$$ (off-gassing volume of polyethylene bags and bottles)

From the ideal gas law, the number of gas moles in the volume is as follows:

$$n_i = \frac{P_v \cdot V_i}{R_u \cdot T_{amb} \cdot 12}$$

A summary of the results obtained using the above equations for each containment vessel arrangement is presented in Tables 3 and 4.

Table 3. Molar quantity of gas generated due to the silicone rubber pad off-gassing

CVA	W_p (g)	V_{po} (in.^{3})	P_V (psia)	R_u (ft-lb/lb-mole·R)	T_{amb} (R)	n_{po} (lb-mole)
1	186.74	9.12	14.7	1545.32	537	1.3458e-05
2	240.09	11.72	14.7	1545.32	537	1.7302e-05
3	160.06	7.81	14.7	1545.32	537	1.1535e-05
4	106.71	5.21	14.7	1545.32	537	7.6901e-06
5	0.00	0.00	14.7	1545.32	537	0.0000e+00
6	0.00	0.00	14.7	1545.32	537	0.0000e+00

Table 4. Molar quantity of gas generated due to polyethylene bag and bottle off-gassing

CVA	W_b (g)	V_{bo} (in.^{3})	P_V (psia)	R_u (ft-lb/lb-mole·R)	T_{amb} (R)	n_{bo} (lb-mole)
1	500.00	213.58	14.7	1545.32	537	3.1529e-04
2	500.00	213.58	14.7	1545.32	537	3.1529e-04
3	500.00	213.58	14.7	1545.32	537	3.1529e-04
4	500.00	213.58	14.7	1545.32	537	3.1529e-04
5	0.00	0.00	14.7	1545.32	537	0.0000e+00
6	500.00	213.58	14.7	1545.32	537	3.1529e-04

III. Total pressure due to off-gassing and HAC temperatures inside the containment vessel

The total pressure of the mixture at 123.85°C (254.93°F), P_T, for each containment vessel arrangement is the sum of each of the previously calculated molar quantities. Table 5 summarizes the molar constituents and total pressure of each containment vessel arrangement. The following equation is used to calculated the final containment vessel pressure:

$$P_{123.85°C} = (\sum n_i \cdot R \cdot T \cdot 12) / V_{GMV},$$

where

n_i = individual molar quantity for each gas,
T = average gas temperature = 123.85°C (254.93°F),
V_{GMV} = V_v = gas mixture volume.

Table 5. Total pressure inside the containment vessel at 123.85°C (254.93°F) [a]

CVA	n_{MNOP} (lb-mole)	n_{po} (lb-mole)	n_{bo} (lb-mole)	n_T (lb-mole)	P_T (psia)
1	3.8549e-04	1.3458e-05	3.1529e-04	7.1424e-04	43.852
2	3.8514e-04	1.7302e-05	3.1529e-04	7.1966e-04	44.108
3	3.7765e-04	1.1535e-05	3.1529e-04	7.0448e-04	44.151
4	3.6547e-04	7.6901e-06	3.1529e-04	6.8845e-04	44.585
5	8.4143e-05	0.0000e+00	0.0000e+00	8.4143e-05	23.668
6	2.9004e-04	0.0000e+00	3.1529e-04	6.0533e-04	49.396

[a] This assumes that the internal convenience cans, polyethylene bottles, and Cat 277-4 spacer cans are sealed.

Table 4.3. Isotopic mass and weight percent for the HEU contents [a]

Nuclide	Weight percent	Mass (g)
U-232	0.000004	0.001440
U-233	0.600000	216.000000
U-234	2.000000	720.000000
U-235	57.095996	20554.558560
U-236	40.000000	14400.000000
U-238	0.000000	0.000000
Transuranic	0.004000	1.440000
Np-237	0.300000	108.000000
Total	100.000000	36000.000000

[a] Weight percent values of individual isotopes are those that generate the largest activity within the allowable ranges presented in Sect. 1.2.3.

Table 4.4. Activity, A_2 value, and number of A_2 proposed for transport

Year	Fast absorption			Medium absorption			Slow absorption		
	Activity (TBq)	A_2 (TBq)	Act / A_2	Activity (TBq)	A_2 (TBq)	Act / A_2	Activity (TBq)	A_2 (TBq)	Act / A_2
0	3.052e-01	1.250e-03	2.442e+02	3.052e-01	1.195e-03	2.555e+02	3.052e-01	1.056e-03	2.8892e+02
5	3.107e-01	1.266e-03	2.454e+02	3.107e-01	1.211e-03	2.567e+02	3.107e-01	1.071e-03	2.9006e+02
10	3.112e-01	1.267e-03	2.456e+02	3.112e-01	1.212e-03	2.568e+02	3.112e-01	1.072e-03	2.9019e+02
20	3.110e-01	1.266e-03	2.457e+02	3.110e-01	1.210e-03	2.569e+02	3.110e-01	1.072e-03	2.9021e+02
30	3.108e-01	1.264e-03	2.458e+02	3.108e-01	1.209e-03	2.570e+02	3.108e-01	1.071e-03	2.9021e+02
40	3.106e-01	1.263e-03	2.459e+02	3.106e-01	1.208e-03	2.571e+02	3.106e-01	1.070e-03	2.9022e+02
50	3.104e-01	1.262e-03	2.460e+02	3.104e-01	1.207e-03	2.572e+02	3.104e-01	1.069e-03	2.9026e+02
60	3.103e-01	1.261e-03	2.461e+02	3.103e-01	1.206e-03	2.573e+02	3.103e-01	1.069e-03	2.9031e+02
70	3.102e-01	1.260e-03	2.462e+02	3.102e-01	1.205e-03	2.575e+02	3.102e-01	1.068e-03	2.9037e+02

4.3 CONTAINMENT UNDER NORMAL CONDITIONS OF TRANSPORT (TYPE B PACKAGES)

Title 10 CFR 71.51(a)(1) specifies that there shall be no loss or dispersal of radioactive contents as demonstrated to a sensitivity of 10^{-6} A_2 per hour, no significant increase in external radiation levels, and no substantial reduction in the effectiveness of the packaging. The initial composition of the HEU contains several isotopes of uranium and transuranic contributors (Table 4.3). As a result of radioactive decay, uranium, transuranics, and daughter product isotopes are present in the HEU contents at varying concentrations depending on the length of decay time. The HEU, with its isotopes and daughter isotopes and contributions from unknown transuranic isotopes, qualifies as a mixture for A_2 determination (Appendix A of 10 CFR 71). The A_2 value and the maximum content activity-to-A_2 value ratio for this mixture have been calculated for several different decay times (Table 4.4). As calculated in Appendix 4.6.1, the A_2 value [1.0682×10^{-3} TBq (2.8870×10^{-2} Ci)] and the maximum content activity-to-A_2 ratio (290.37) used to qualify this package occurs at about 70 years of decay. As previously stated, these values have been determined using a bounding case maximum of 36 kg of HEU with isotopic weight percent values as shown in Table 4.3. The specified composition is a very conservative upper bound achieved by using the maximum weight percent values for the higher specific activity isotopes (^{232}U, ^{233}U, ^{234}U, and ^{236}U), including contributions from other transuranics and ^{237}Np.

The maximum activity, minimum A_2, and minimum leakage requirements were determined for this worst case scenario and are presented in Tables 4.4 and 4.5. These masses and isotopic concentrations were used for the proposed contents without regard to limits established based on shielding and subcriticality considerations. The actual mass limits affirmed for this shipping package are established in Sect. 1 (Table1.3). The analyses conducted in Appendix 4.6.2 assumes that the total mass of uranium for each component is available for release as an aerosol (worst case). From experimental tests, the maximum aerosol density containing uranium particulate was reported in *Leakage of Radioactive Powders from Containers* (Curren and Bond 1980) to be 9.0×10^{-6} g/cm^3. This aerosol density is used to calculate the total activity concentration in ANSI N14.5-1997, Section B.15, examples 13, 27, and 29.

The containment criteria for the ES-3100 package will be leaktight (defined in paragraph 2.1 of ANSI N14.5-1997 as having a leakage rate $\leq 1 \times 10^{-7}$ ref-cm^3/s) during the prototype tests. This leaktight criterion satisfies the design verification requirement stipulated in paragraph 7.2.4 of ANSI N14.5-1997. The requirements of ANSI N14.5-1997 are used for all stages of containment verification for the ES-3100 (i.e., design, fabrication, maintenance, periodic and preshipment).

The design, fabrication, maintenance and periodic leakage rate limit is 1×10^{-7} ref-cm^3/s air. The pass criterion for the preshipment leakage rate test, which demonstrates correct assembly of the containment vessels, is 1×10^{-4} ref-cm^3/s, which exceeds the requirements given in ANSI N14.5, paragraph 7.6.4. In accordance with the definition of sensitivity of a leakage test procedure provided in Sections 2 and 7.6.4 of ANSI N14.5-1997, the minimum acceptable leakage rate that the procedure needs to be capable of detecting is 1×10^{-3} ref-cm^3/s. The requirements for the ES-3100 exceed the regulatory criterion by specifying a leakage rate of $\leq 1 \times 10^{-4}$ ref-cm^3/s, and equipment used in accordance with Section 7.6.4 of ANSI N14.5-1997 would not detect this leakage. The preshipment, fabrication, maintenance and periodic leakage rate tests are required to be conducted on each containment vessel in accordance with ANSI N14.5 and are specified in Chapters 7 and 8. These leakage rates are not dependent on filters or mechanical cooling.

The complete design verification testing of the ES-3100 package for NCT was conducted on test unit TU-4. Since the containment vessel was assembled at ambient conditions, the pressure was nominally 101.35 kPa (14.70 psia) at 25°C (77°F). In accordance with 10 CFR 71.71(b), the initial pressure inside each containment vessel should be the maximum normal operating pressure (MNOP). As calculated in

Table 4.7. Regulatory leakage criteria for HAC [a]

Verification activity	Fast absorption		Medium absorption		Slow absorption	
	L_{RA-air} (ref-cm³/s)	L_{RA-He} (cm³/s)	L_{RA-air} (ref-cm³/s)	L_{RA-He} (cm³/s)	L_{RA-air} (ref-cm³/s)	L_{RA-He} (cm³/s)
Design	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[a] The procedure used to calculate the above criteria is shown in Appendix 4.6.2.

Table 4.8 Containment vessel design verification tests for HAC

Test Type	Test Values	Leakage test procedure
	Design and compliance leakage testing	
Design verification of O-ring seal (air)	$L_T \leq 1.0 \times 10^{-4}$ ref-cm³/s	See Appendix 2.10.7
Design verification of containment vessel boundary (helium)	$L_T \leq 2.0 \times 10^{-7}$ cm³/s	See Appendix 2.10.7

lid was drilled and tapped for a helium leak-check port. The entire containment boundary was then helium leak checked and passed the leaktight criteria. Also, no visible water was seen inside the inner O-ring groove of Test Unit-6 and no water was observed inside any of the other test units.

To verify the entire containment boundary to the leaktight criteria, the containment vessels of Test Units-1 through -5 were helium leak tested using the procedure shown in the test report (Appendix 2.10.7). These test units had previously been subjected to the drop test stipulated in 10 CFR 71.71 (c)(6) and the sequential tests stipulated in 10 CFR 71.73 except for Test Unit-4, which had been first subjected to the testing in accordance with 10 CFR 71.71. The maximum recorded helium leak rate for any of these containment vessels was 2.0×10^{-7} cm³/s after 20 min of testing on Test Unit-4 as documented in Section 5.2 of the test report (Appendix 2.10.7). Test Units-2 and -5 displayed some unusual pulsing action during leak testing. The peak amplitude changed after adding helium in a manner expected for diffusion through the O-rings rather than a rise immediately following the addition of helium that would indicate a leak to the outside of the containment vessel. This is further discussed and graphically presented on pages 88 through 91 of the ES-3100 test report (Appendix 2.10.7). These measured leakage rates verify that the containment vessels are leaktight in accordance with ANSI N14.5-1997. Therefore, the containment boundary of the ES-3100 package was maintained during the HAC testing.

The 36 kg of HEU content is unirradiated; therefore, only very small quantities of fission gas products will be produced from spontaneous fission and subcritical neutron induced fission. Fission gas products are produced in such small quantities that they have no measurable effect on the releasable content source term or containment vessel pressurization. Fission gas products will not be considered further in this SAR.

4.5 LEAKAGE RATE TESTS FOR TYPE B PACKAGES

The maximum allowable release of radioactive material allowed by 10 CFR 71.51(a)(2) under HAC is A_2 in one week. Title 10 CFR 71.51(a)(2) also specifies that there be no escape of ^{85}Kr exceeding 10 A_2 in one week. ANSI N14.5-1997 specifies the leakage test methods and leakage rates that are accepted in Nuclear Regulatory Commission (NRC) Regulatory Guide 7.4 as demonstrating that a package meets the 10 CFR 71.51(a)(2) requirements for containment. The containment criteria for the ES-3100 package will be leaktight, defined in ANSI N14.5 paragraph 2.1 as having a leakage rate $\leq 1 \times 10^{-7}$ ref-cm^3/s, during the prototype tests. This leaktight criterion satisfies the design verification requirement stipulated in paragraph 7.2.4 of ANSI N14.5-1997. The requirements of ANSI N14.5-1997 are used for all stages of containment verification for the ES-3100 (i.e., design, fabrication, maintenance, periodic and preshipment). The design, fabrication, maintenance and periodic leakage rate limit is 1×10^{-7} ref-cm^3/s air (or 2.0×10^{-7} cm^3/s helium). The pass criterion for the preshipment leakage rate test, which demonstrates correct assembly of the containment vessels, is 1×10^{-4} ref-cm^3/s, which exceeds the requirements given in ANSI N14.5-1997, paragraph 7.6.4. In accordance with the definition of sensitivity of a leakage test procedure provided in Sections 2 and 7.6.4 of ANSI N14.5-1997, the minimum acceptable leakage rate that the procedure needs to be capable of detecting is 1×10^{-3} ref-cm^3/s. The requirements for the ES-3100 exceed the regulatory criterion by specifying a leakage rate of $\leq 1 \times 10^{-4}$ ref-cm^3/s, and equipment used in accordance with Section 7.6.4 of ANSI N14.5-1997 would not detect this leakage. The preshipment, fabrication, maintenance, and periodic leakage rate tests are required to be conducted on each containment vessel in accordance with ANSI N14.5-1997 and are specified in Chapters 7 and 8. These leakage rates are not dependent on filters or mechanical cooling.

The requirements of ANSI N14.5-1997 are used for all stages of containment verification for the ES-3100; the design (HAC test) leakage rate limit is 1×10^{-7} ref-cm^3/s (which is defined as leaktight in ANSI N14.5-1997). The packaging has been shown to maintain containment before and after prototype testing by leakage tests performed for containment verification to the requirements of ANSI N14.5-1997. Test Unit-4's containment vessel was subjected to both the NCT and HAC tests. Test Units-1 through -5 were subjected to the free drop stipulated in 10 CFR 71.71(c)(7) and to the sequential HAC test stipulated in 10 CFR 71.73. Following these tests, each containment vessel was helium leak tested in accordance with the test plan. Again, the test results verified that the containment vessels were leaktight. Thus, there could be no release of radioactive materials from the containment vessels. These leakage rates are not dependent on filters or mechanical cooling. These measured leakage rates verify that the containment vessels are leaktight in accordance with ANSI N14.5-1997.

Therefore, the ES-3100 package meets the containment criteria as specified in 10 CFR 71.73 for HAC when shipping the proposed 36 kg of HEU in the containment vessel.