Department of Energy
Washington, DC 20585

April 17, 2024

Bernard H. White IV, Senior Project Manager
Storage and Transportation Licensing Branch
U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
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Dear Bernard White,

In response to your request for supplemental information (RSI) dated April 1, 2024, regarding Docket No. 71-9315, EPID No. L-2022-LLA-0116, the U.S. Department of Energy (DOE) provided the requested documents on a DOE secure website. The files were subsequently downloaded by NRC staff (Pierre Saverot), as confirmed by your email to Lawrence Gelder on April 2, 2024. Enclosed is DOE's response to the three observations in the RSI.

If you have any questions or need more details, please contact Lawrence Gelder at 803-645-3430 or lawrence.gelder@em.doe.gov.

Julia C. Shenk
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Julia C. Shenk
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Director
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19901 Germantown Road – Room D115
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Enclosed: Response to 71-9315 Observations

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

Sol Arroyo-Solá, Y-12 Field Office
L.F. Gelder, CONTR
DOE Docket 23-34-9315

Observations with applicant responses

3.0 Thermal Evaluation

OBS-Th-1

Provide the calculation that supports the minimum required CV void volume of 42.779 in3 (approximated as 43 in3, per SAR section 1.2.2.4) and discuss the application of that void volume and relevant bounding content in the analyses found in SAR appendix 3.5.1, appendix 3.5.2, and appendix 3.5.4. Although SAR table 1 in appendix 3.5.1 mentions a 42.779 in3 minimum void volume for the containment vessel arrangement (CVA) in item 11 (CVA 11), the determination of this void volume to ensure acceptable gas expansion and offgassing was not readily apparent. In addition, although CVA 11 is mentioned in appendix 3.5.1 and appendix 3.5.2, it was not clear what bounding content was transported in the analyses. Likewise, although 5 volume percent hydrogen concentration acceptance criterion is dependent on minimum volumes, a reason was not provided that explained why the CVA 11 minimum volume was not explicitly mentioned in appendix 3.5.4 for hydrogen gas buildup. This information is needed to determine compliance with 10 CFR 71.35 and 71.43(d).

OBS-Th-1 Response

The 11th item listed in the first paragraph of Sect. 3.1.4.1 shall be revised to read as follows:

11. One shipment will contain closed cans with diameters >4.25 in. In this situation, the void volume inside the loaded CV must be ≥ 43 in.^{3} and the structural volume of the cans can't exceed 7.84 in.^{3}

Table 3.6 shall be revised to read as follows:

Table 3.6. Total pressure inside the containment vessel at 89.60°C (193.28°F)

CVA [a]	n_a [b] (lb-mol)	n_v [b] (lb-mol)	n_{po} [b] (lb-mol)	n_{bo} [b] (lb-mol)	n_{tf} [b] (lb-mol)	n_{H2} [b] (lb-mol)	n_{O2} [b] (lb-mol)	n_T [b] (lb-mol)	P_T (psia)
1 [a]	6.4075E-04	2.0884E-05	0.0000E+00	0.0000E+00	0.0000E+00	3.5761E-05	1.7881E-05	7.1528E-04	19.333
7 [a]	4.5248E-04	2.5459E-04 [c]	0.0000E+00	0.0000E+00	2.2296E-05	2.4457E-05	1.2228E-05	7.6605E-04	30.276
11 [d]	6.1157E-05	1.9932E-06	0.0000E+00	0.0000E+00	0.0000E+00	3.4133E-06	1.7067E-06	6.8270E-05	19.333

[a] This assumes that the internal convenience cans, polyethylene or Teflon FEP bottles, and Cat 277-4 spacer cans are not sealed.

[b] n_a—molar quantity of dry air in the gas mixture;
n_v—molar quantity of water vapor in the gas mixture;
n_{po}—molar quantity of gas due to offgassing of the silicone rubber pads;
n_{bo}—molar quantity of gas due to offgassing of the polyethylene, nylon, or Teflon bags; polyethylene bottles; and lifting sling;
n_{tf}—molar quantity of gas due to offgassing of the Teflon bottles;
n_{H2}—molar quantity of hydrogen gas due to radiolysis of water;
n_{O2}—molar quantity of oxygen gas due to radiolysis of water; and
n_T—total molar quantity in the gas mixture.

[c] This value is the molar quantity of water vapor generated from the efflorescence of UNX crystals.

[d] This assumes that the internal convenience cans are sealed. However, hydrogen and oxygen gases have been added for conservatism. A minimum free volume of ~43 in.^{3} is used in the above calculations.

The sixth item listed in the first paragraph of Sect. 3.1.4.2 shall be revised to read as follows:

6. CVAs that utilize closed convenience cans with a diameter greater than 10.8 cm (4.25 in.) will have a minimum void volume of ≥ 43 in.^{3} for gas evolution and expansion; and the overall structural volume of the convenience cans can't exceed 7.84 in.^{3};

Table 3.7 shall be revised to read as follows:

Table 3.7. Total pressure inside the containment vessel at 167.39°C (333.31°F) [a] with efflorescence

CVA	n_{MNOP} [b] (lb-mol)	n_{po} [b] (lb-mol)	n_{bo} [b] (lb-mol)	n_{tf} [b] (lb-mol)	n_{r-H2} [b] (lb-mol)	n_{r-O2} [b] (lb-mol)	n_{CE-WV} [b,c] (lb-mol)	n_T [b] (lb-mol)	P_T (psia)
1 [a]	8.7016E-04	1.6486E-05	4.0537E-04	0.0000E+00	3.5761E-05	1.7881E-05	0.0000E+00	1.3457E-03	44.168
7 [a]	9.3193E-04	0.0000E+00	4.0537E-04	2.2296E-05	2.4457E-05	1.2229E-05	2.2490E-03	3.6453E-03	174.950
11 [d]	8.3054E-05	1.6487E-05	4.0537E-04	0.0000E+00	3.4133E-06	1.7067E-06	0.0000E+00	5.1003E-04	174.949

[a] This assumes that the internal convenience cans, polyethylene or Teflon FEP bottles, and Cat 277-4 spacer cans are not sealed.

[b] n_{MNOP}—molar quantity of the gas mixture at maximum normal operating pressure at standard temperature [25°C (77°F)];
n_{po}—molar quantity of gas due to offgassing of the silicone rubber pads;
n_{bo}—molar quantity of gas due to offgassing of the polyethylene, nylon, or Teflon bags, polyethylene bottles, and lifting sling;
n_{tf}—molar quantity of gas due to offgassing of the Teflon bottles;
n_{r-H2}—molar quantity of hydrogen gas due to radiolysis of water;
n_{r-O2}—molar quantity of oxygen gas due to radiolysis of water;
n_{CE-WV}—molar quantity of water vapor due to efflorescence of UNX crystals; and
n_T—total molar quantity in the gas mixture.

[c] Efflorescence of UNX crystals as water vapor.

[d] This assumes that the internal convenience cans are sealed. However, hydrogen and oxygen gases have been added for conservatism. A minimum free volume of ~43 in.^{3} is used in the above calculations.

Appendix 3.5.1

The 11th item listed in the first paragraph of Appendix 3.5.1 shall be revised to read as follows:

11. one shipment will contain closed cans with diameters >4.25 in. In this situation, the void volume inside the loaded CV must be ≥ 43 in.^{3} in order to not exceed the previously high pressure prediction for containment vessel arrangement (CVA) 7. In addition, the structural volume of the convenience cans can't exceed 7.84 in.^{3}

The first sentence in the third paragraph of Sect. I in Appendix 3.5.1 shall be revised to read as follows:

The bounding case for oxide material contained in 4.25-in–diam cans based on the volumes listed in Table 1 is CVA 1 at 574.66 in.^{3}.

The entry for CVA 11 in Table 1 of Appendix 3.5.1 shall be revised to read as follows:

Table 1. Containment vessel void volume for each CVA

CVA		V_{ECV} (in.^{3})	V_{SP} [a] (in.^{3})	V_{PB} (in.^{3})	V_{SCC} (in.^{3})	V_{CS} (in.^{3})	V_{CH} (in.^{3})	V_V (in.^{3})
11	Closed convenience cans with diameters greater 4.25-in. Seven silicone pads				≤ 7.84			42.779 (min.)

The last three sentences in the paragraph immediately following Table 1 in Appendix 3.5.1 shall be deleted and replaced with the following:

The bounding case for all materials contained in cans with a diameter >4.25 in. (CVA 11) is determined by not exceeding the maximum predicted HAC pressure previously determined for CVAs 1 and 7 and assumes these cans are sealed. The hydrogen and oxygen gases have been added for conservatism. A minimum void volume of 42.779 in.^{3} in the containment vessel of CVA 11 has been back calculated to meet this HAC pressure criteria. This value is conservatively rounded up to 43 in.^{3}

Table 7 in Appendix 3.5.1 shall be revised to read as follows:

Table 3.7. Total pressure inside the containment vessel at 89.60°C (193.28°F)

CVA [a]	n_a [b] (lb-mol)	n_v [b] (lb-mol)	n_{po} [b] (lb-mol)	n_{bo} [b] (lb-mol)	n_{tf} [b] (lb-mol)	n_{H2} [b] (lb-mol)	n_{O2} [b] (lb-mol)	n_T [b] (lb-mol)	P_T (psia)
1 [a]	6.4075E-04	2.0884E-05	0.0000E+00	0.0000E+00	0.0000E+00	3.5761E-05	1.7881E-05	7.1528E-04	19.333
7 [a]	4.5248E-04	2.5459E-04 [c]	0.0000E+00	0.0000E+00	2.2296E-05	2.4457E-05	1.2228E-05	7.6605E-04	30.276
11 [d]	6.1157E-05	1.9932E-06	0.0000E+00	0.0000E+00	0.0000E+00	3.4133E-06	1.7067E-06	6.8270E-05	19.333

[a] This assumes that the internal convenience cans, polyethylene or Teflon FEP bottles, and Cat 277-4 spacer cans are not sealed.
[b] n_a—molar quantity of dry air in the gas mixture;
n_v—molar quantity of water vapor in the gas mixture;
n_{po}—molar quantity of gas due to offgassing of the silicone rubber pads;
n_{bo}—molar quantity of gas due to offgassing of the polyethylene, nylon, or Teflon bags; polyethylene bottles; and lifting sling;
n_{tf}—molar quantity of gas due to offgassing of the Teflon bottles;
n_{H2}—molar quantity of hydrogen gas due to radiolysis of water;
n_{O2}—molar quantity of oxygen gas due to radiolysis of water; and
n_T—total molar quantity in the gas mixture.
[c] This value is the molar quantity of water vapor generated from the efflorescence of UNX crystals.
[d] This assumes that the internal convenience cans are sealed. However, hydrogen and oxygen gases have been added for conservatism. A minimum free volume of ~43 in.^{3} is used in the above calculations.

Table 8 in Appendix 3.5.1 shall be revised as follows:

Table 8. Total molar quantities inside the containment vessel

CVA [a]	n_a [b] (lb-mol)	n_v [b] (lb-mol)	n_{po} [b] (lb-mol)	n_{bo} [b] (lb-mol)	n_{tf} [b] (lb-mol)	n_{H2} [b] (lb-mol)	n_{O2} [b] (lb-mol)	n_T [b] (lb-mol)
1 [a]	6.4075E-04	2.0884E-05	0.0000E+00	0.0000E+00	0.0000E+00	3.5761E-05	1.7881E-05	7.1528E-04
11 [d]	6.1157E-05	1.9933E-06	0.0000E+00	0.0000E+00	0.0000E+00	3.4133E-06	1.7066E-06	6.8270E-05

[a] This assumes that the internal convenience cans, polyethylene or Teflon FEP bottles, and Cat 277-4 spacer cans are not sealed.
[b] n_a—molar quantity of dry air in the gas mixture;
n_v—molar quantity of water vapor in the gas mixture;
n_{po}—molar quantity of gas due to offgassing of the silicone rubber pads;
n_{bo}—molar quantity of gas due to offgassing of the polyethylene, nylon, or Teflon bags, polyethylene bottles, and lifting sling;
n_{tf}—molar quantity of gas due to offgassing of the Teflon bottles;
n_{H2}—molar quantity of hydrogen gas due to radiolysis of water;
n_{O2}—molar quantity of oxygen gas due to radiolysis of water; and
n_T—total molar quantity in the gas mixture.
[c] This value is the molar quantity of water vapor generated from the efflorescence of UNX crystals.
[d] This assumes that the internal convenience cans are sealed. However, hydrogen and oxygen gases have been added for conservatism. A minimum free volume of ~43 in.^{3} is used in the above calculations.

Appendix 3.5.2

The 11th item listed in the first paragraph of Appendix 3.5.2 shall be revised to read as follows:

11. one shipment will contain closed cans with diameters >4.25 in. In this situation, the void volume inside the loaded CV must be ≥ 43 in.^{3} in order to not exceed the previously high pressure prediction for containment vessel arrangement (CVA) 7. In addition, the structural volume of the convenience cans can't exceed 7.84 in.^{3}

Table 1 of Appendix 3.5.2 shall be revised to read as follows:

Table 1. Total pressure inside the containment vessel at 89.60°C (193.28°F) [a]

CVA	n_a [b] (lb-mol)	n_v [b] (lb-mol)	n_{po} [b] (lb-mol)	n_{bo} [b] (lb-mol)	n_{tf} [b] (lb-mol)	n_{H2} [b] (lb-mol)	n_{O2} [b] (lb-mol)	n_T [b] (lb-mol)	P_T (psia)
1 [a]	6.4075E-04	2.0884E-05	0.0000E+00	0.0000E+00	0.0000E+00	3.5761E-05	1.7881E-05	7.1528E-04	19.333
7 [a]	4.5248E-04 [c]	2.5459E-04 [c]	0.0000E+00	0.0000E+00	2.2296E-05	2.4457E-05	1.2228E-05	7.6605E-04	30.276
11 [d]	6.11576E-05	1.99338E-06	0.0000E+00	0.0000E+00	0.0000E+00	3.413385E-06	1.7067E-06	6.827077E-05	19.333

[a] This assumes that the internal convenience cans, polyethylene or Teflon FEP bottles, and Cat 277-4 spacer cans are not sealed.

[b] n_a—molar quantity of dry air in the gas mixture;
n_v—molar quantity of water vapor in the gas mixture;
n_{po}—molar quantity of gas due to offgassing of the silicone rubber pads;
n_{bo}—molar quantity of gas due to offgassing of the polyethylene, nylon, or Teflon bags; polyethylene bottles; and lifting sling;
n_{tf}—molar quantity of gas due to offgassing of the Teflon bottles;
n_{H2}—molar quantity of hydrogen gas due to radiolysis of water;
n_{O2}—molar quantity of oxygen gas due to radiolysis of water; and
n_T—total molar quantity in the gas mixture.

[c] For CVA 7, using 100% dry air at containment vessel closure and the saturated vapor pressure at temperature for the water vapor constituent, the highest pressure is generated.

[d] This assumes that the internal convenience cans are sealed. However, hydrogen and oxygen gases have been added for conservatism. A minimum free volume of ~43 in.^{3} is used in the above calculations.

Table 7 of Appendix 3.5.2 shall be revised to read as follows:

Table 7. Total pressure inside the containment vessel at 167.39°C (333.31°F) with efflorescence

CVA ~~a~~	n_{MNOP} [b] (lb-mol)	n_{po} [b] (lb-mol)	n_{bo} [b] (lb-mol)	n_{tf} [b] (lb-mol)	n_{r-H2} [b] (lb-mol)	n_{r-O2} [b] (lb-mol)	n_{CE-WV} [b, c] (lb-mol)	n_T [b] (lb-mol)	P_T (psia)
1 [a]	8.7016E-04	1.6486E-05	4.0537E-04	0.0000E+00	3.5761E-05	1.7881E-05	0.0000E+00	1.3457E-03	44.168
7 [a]	9.3193E-04	0.0000E+00	4.0537E-04	2.2296E-05	2.4457E-05	1.2228E-05	2.2490E-03	3.6453E-03	174.950
11 [d]	8.3054E-05	1.6487E-05	4.0537E-04	0.0000E+00	3.4133E-06	1.7067E-06	0.0000E+00	5.1003E-04	174.949

[a] This assumes that the internal convenience cans, polyethylene or Teflon FEP bottles, and Cat 277-4 spacer cans are not sealed.

[b] n_{MNOP}—molar quantity of the gas mixture at maximum normal operating pressure at standard temperature [25°C (77°F)];
n_{po}—molar quantity of gas due to offgassing of the silicone rubber pads;
n_{bo}—molar quantity of gas due to offgassing of the polyethylene, nylon, or Teflon bags, polyethylene bottles, and lifting sling;
n_{tf}—molar quantity of gas due to offgassing of the Teflon bottles;
n_{r-H2}—molar quantity of hydrogen gas due to radiolysis of water;
n_{r-O2}—molar quantity of oxygen gas due to radiolysis of water;
n_{CE-WV}—molar quantity of water vapor due to efflorescence of UNX crystals; and
n_T—total molar quantity in the gas mixture.

[c] Efflorescence of UNX crystals as water vapor.

[d] This assumes that the internal convenience cans are sealed. However, hydrogen and oxygen gases have been added for conservatism. A minimum free volume of ~43 in.^{3} is used in the above calculations.

Appendix 3.5.4

The second paragraph in Sect. 3.5.4.2 of Appendix 3.5.4 shall be revised to read as follows:

The ES-3100 has several CVAs (see Appendix 3.5.1, Table 1) for the convenience containers. CVA 7 consists of three Teflon bottles and is the only arrangement for UNX. CVAs 5 (nickel alloy cans) and 6 (polyethylene bottles) can only be used for oxides while the remaining CVAs (steel cans) may be used for oxides or metal including CVA 11. The bounding arrangement for oxides is CVA 1 (6 steel cans) because it has the smallest free volume [574.66 in.^{3} (Appendix 3.5.1, Table 1)] provided that the total structural volume of the convenience cans used in CVA 11 don't exceed 7.84 in.^{3} and the convenience cans are assumed not to be sealed for the following shipment duration calculations. The contents of CVA 11 consist of 15.13 kg of oxides with the molecular distribution described in Table 3.5.4.1 which is the same as CVA 1. Therefore CVA 1 bounds the limit for shipment durations.

OBS-Th-2

Clarify that package temperatures would remain below allowable values during NCT and fire HAC when multiple packages are placed within the enclosed conveyance mentioned in SAR section 7.1.3.2. Enclosure SAR section 3.1.2 noted that the package decay heat is 5 W (an increase from the previous 0.4 W value). Considering that SAR section 6.1.3 noted that multiple packages can be shipped together, the thermal analyses did not address the potential impact of increased package temperatures from multiple packages within an enclosed conveyance with reduced heat transfer to the ambient. For example, although SAR table 3.3 provided the NCT temperature of the O-ring seals based on the stand-alone thermal model assumption, the extent of the temperature margin with the O-ring allowable value is uncertain when multiple packages are positioned within a single enclosure with reduced heat transfer. This information is needed to determine compliance with 10 CFR 71.35.

OBS-Th-2 Response

The stipulations put forward by 10 CFR 71.35 and subsequently 71.59 and 71.71(c) do not speak to package temperature requirements when shipping an array of packages in a conveyance. The analysis

conducted in DAC M801794-0002 analyzed a singular ES-3100 package subjected to NCT thermal conditions prescribed in 10 CFR 71.71 Analyzing multiple packages in an array while subjected to the thermal conditions has not been requested in prior submittals of the ES-3100 SAR. If required for this submittal, extensive additional modeling efforts would be necessary and would require input from the review panel for boundary and thermal conditions. Additionally, this would incur the need for revisions in Chapters 2, 3, and 4.

4.0 Containment Evaluation

OBS-Co-1

Clarify the leakage rate test results (e.g., "leaktight") of the ES-3100 Test Units (TU) described in SAR section 4.2. SAR section 4.2 indicated that the ES-3100 design verification leakage rate testing included a TU-4 leakage rate between O-rings of 2.4773E-5 ref cm^3/sec (air) and a subsequent entire TU-4 containment boundary leakage rate test result of 2E-7 cm^3/sec (helium). An analysis or discussion was not provided that explains reasons for designating a package as being ANSI N14.5 "leaktight" (which is the basis for the package's operation) when part of the containment boundary has a 2.4773E-5 ref cm^3/sec (air) leak rate. This information is needed to determine compliance with 10 CFR 71.35, 10 CFR 71.51.

OBS-Co-1 Response

Paragraphs 6 and 7 in Sect.; 4.2 shall be deleted and replaced with the following paragraph:

Following the design verification testing of paragraphs 10 CFR 71.71(c)(5) through 71.71(c)(10) excluding 71.71(c)(8), TU-4 was subjected to the sequential testing of paragraphs 10 CFR 71.73(c)(1) through (c)(4). Upon removal of the CV from the drum assembly, the cavity between the O-rings was leak checked. This unit recorded a leak rate between the O-rings of 2.4773 × 10−5 ref-cm3 /s (ORNL/NTRC-013). This leak check was conducted to verify that the O-rings were still in place and undamaged by testing. Since this test included an outer O-ring that is not assumed part of the containment boundary, the entire containment boundary of TU-4 was helium leak tested to a value ≤ 2 × 10−7 cm3 /s, thereby verifying a leak-tight boundary. The leak-test procedure followed to verify this criterion is documented in the ES-3100 test report (ORNL/NTRC-013). The maximum recorded helium leakage rate for this CV was 2.0 × 10 −7 cm3 /s after 20 min of testing. Visual inspection following the testing indicated that neither the vessel body, the O-rings, the seal areas, nor the vessel lid assembly were damaged during the tests. Pictures taken of the CV top following testing showed that the closure nut had rotated a maximum of 0.15 cm (0.060 in.) from its original radial position obtained during assembly. Based on the pitch of the closure nut, this rotation translates into only 0.0013 cm (0.0005 in.) decompression of the O-rings. This compares to the original nominal compression of 0.064 cm (0.025 in.). Therefore, O-ring compression was maintained during compliance testing. Based on these results, the ES-3100 package meets and exceeds the containment criteria specified in 10 CFR 71.51 for NCT when used to ship the contents described in Sect. 1.2.2.