East Building, PHH-23
1200 New Jersey Ave, SE
Washington, D.C. 20590

U.S. Department of Transportation

Pipeline and Hazardous Materials Safety Administration

COMPETENT AUTHORITY CERTIFICATION FOR A TYPE B(U)F FISSILE RADIOACTIVE MATERIALS PACKAGE DESIGN CERTIFICATE USA/9315/B(U)F-96, REVISION 17

The Competent Authority of the United States certifies that the radioactive material package design described in this certificate satisfies the regulatory requirements for a Type B(U)F package for fissile material as prescribed in the regulations of the International Atomic Energy Agency[1] and the United States of America[2] The package design is approved for use within the United States for import and export shipments made in accordance with applicable international and domestic transport regulations.

1. Package Identification - ES-3100.

2. Package Description and Authorized Radioactive Contents - as described in U.S. Department of Energy Certificate of Compliance No. 9315, Revision 19 (attached).

3. Criticality - The minimum criticality safety index is as defined in the DOE Certificate of Compliance. The maximum number of packages per conveyance is determined in accordance with Table 11 of the IAEA regulations cited in this certificate.

4. General Conditions -

   a. Each user of this certificate must have in his possession a copy of this certificate and all documents necessary to properly prepare the package for transportation. The user shall prepare the package for shipment in accordance with the documentation and applicable regulations.

   b. Each user of this certificate, other than the original petitioner, shall register his identity in writing to the Office of Engineering and Research, (PHH-23), Pipeline and Hazardous

[1] "Regulations for the Safe Transport of Radioactive Material, 2012 Edition, No. SSR-6" published by the International Atomic Energy Agency (IAEA), Vienna, Austria.

[2] Title 49, Code of Federal Regulations, Parts 100-199, United States of America.

Materials Safety Administration, U.S. Department of Transportation, Washington D.C. 20590-0001.

c. This certificate does not relieve any consignor or carrier from compliance with any requirement of the Government of any country through or into which the package is to be transported.

d. Records of Management System activities required by Paragraph 306 of the IAEA regulations[1] shall be maintained and made available to the authorized officials for at least three years after the last shipment authorized by this certificate. Consignors in the United States exporting shipments under this certificate shall satisfy the applicable requirements of Subpart H of 10 CFR 71.

5. Special Conditions -

a. Transport by air is not authorized, except as specified in Section (b) Contents, Sub Section (d) Conditions contained in U.S. Department of Energy Certificate of Compliance No. 9315, Revision 19.

b. All requirements found in Section (b) Contents, Sub Section (d) Conditions contained in U.S. Department of Energy Certificate of Compliance No. 9315, Revision 19 shall be satisfied.

6. Marking and Labeling - The package shall bear the marking USA/9315/B(U)F-96 in addition to other required markings and labeling.

7. Expiration Date - This certificate expires on July 31, 2025. Previous editions which have not reached their expiration date may continue to be used.

CERTIFICATE USA/9315/B(U)F-96, REVISION 17

This certificate is issued in accordance with paragraph(s) 810 and 816 of the IAEA Regulations and Section 173.471 and 173.472 of Title 49 of the Code of Federal Regulations, in response to the November 28, 2022 petition by Department of Energy, Washington, DC, and in consideration of other information on file in this Office.

Certified By:

William Schoonover
Associate Administrator for Hazardous Materials Safety

December 13, 2022
(DATE)

Revision 17 - Issued to endorse U.S. Department of Energy Certificate of Compliance No. 9315, Revision 19.

U.S. DEPARTMENT OF ENERGY

DOE Packaging Certification Program

CERTIFICATE OF COMPLIANCE
For Radioactive Materials Package

OE F 5822.1
5-85 (Formerly EV-618)

1a. Certificate Number	1b. Revision No.	1c. Package Identification No.	1d. Page No.	1e. Total No. Pages
9315	19	USA/9315/B(U)F-96 (DOE)	1	15

2. PREAMBLE

2a. This certificate is issued under the authority of 49 CFR Part 173.7(d).

2b. The packaging and contents described in Item 5 below meet the safety standards set forth in subpart E, "Package Approval Standards" and subpart F, "Package Special Form, and LSA-III Tests" Title 10, Code of Federal Regulations, Part 71.

2c. This certificate does not relieve the consignor from compliance with any requirement of the regulations of the U.S. Department of Transportation or other applicable regulatory agencies, including the government of any country through or into which the package will be transported.

3. This certificate is issued on the basis of a safety analysis report of the package design or application —

(1) Prepared by (*Name and Address*):	(2) Title and identification of report or application:	(3) Date:
U.S. Department of Energy NNSA Y-12 National Security Complex P.O. Box 2009 Oak Ridge, TN 37831	Safety Analysis Report for Packaging (SARP) Y-12 National Security Complex, Model ES-3100 Package with Bulk HEU Contents, SP-PKG-801940-A001, Revision 3, dated January 21, 2021	January 21, 2021

4. CONDITIONS

This certificate is conditional upon fulfilling of the applicable Operational and Quality Assurance requirements of 49CFR parts 100 – 199 and 10CFR Part 71, and the conditions specified in Item 5 below.

5. Description of Packaging and Authorized Contents, Model Number, Transport Index, other Conditions, and References:

(a) Packaging

(1) Model Number: ES-3100

(2) Description:

The ES-3100 packaging, which is depicted in Figure 1.1 below, is a cylindrical container that is approximately 43.5 inches (110 cm) in overall height, including the cover and lid and approximately 19 inches (49 cm) in overall diameter.

The packaging is composed of an outer drum assembly and an inner containment vessel (CV). The main functions of the packaging are to provide containment, shielding, and nuclear criticality safety. Table 2.7 of the SARP provides detailed material specifications for the packaging components.

The outer drum assembly consists of (a) a reinforced stainless steel, standard military specification 30 gallon drum with an increased length; (b) a cylindrical layer of castable refractory material (Kaolite®1600 or Packcrete), which is comprised of concrete and vermiculite, and which acts as both an impact-absorbing and thermal-insulating material; (c) a cylindrical layer of castable refractory (277-4 special dry mix) for neutron attenuation; (d) an inner steel liner; and (e) a removable top plug that also has a layer of the castable refractory material (Kaolite®1600 or Packcrete) for impact absorption and thermal insulation. The 30-gallon drum is manufactured from 16-gauge Type 304

6a. Date of Issuance: November 22, 2022	6b. Expiration Date: July 31, 2025

FOR THE U.S. DEPARTMENT OF ENERGY

7a. Address *(of DOE Issuing Office)*	7b. Signature, Name, and Title *(of DOE Approving Official)*
U.S. Department of Energy Office of Packaging and Transportation, EM-4.24 1000 Independence Avenue, SW Washington, DC 20585	Julia C. Shenk JULIA SHENK Digitally signed by JULIA SHENK Date: 2022.11.22 10:15:02 -05'00' Director Headquarters Certifying Official Office of Packaging and Transportation

or 304L stainless steel. The fabrication is accomplished according to requirements specified in NUREG/CR-3854, and is in accordance with the dimensional requirements of MIL-D-6054F as modified according to Drawing M2E801580A004. The inner liner is also manufactured from Type 304 or 304L stainless steel.

An ARG-US radiofrequency identification (RFID) tag may be attached to the ES-3100 package if desired. If an ARG-US RFID tag is attached to the package using the drum stud and nut assembly, the normal thread engagement of the external nut shall not be affected when compared to adjacent stud and nut attachments.

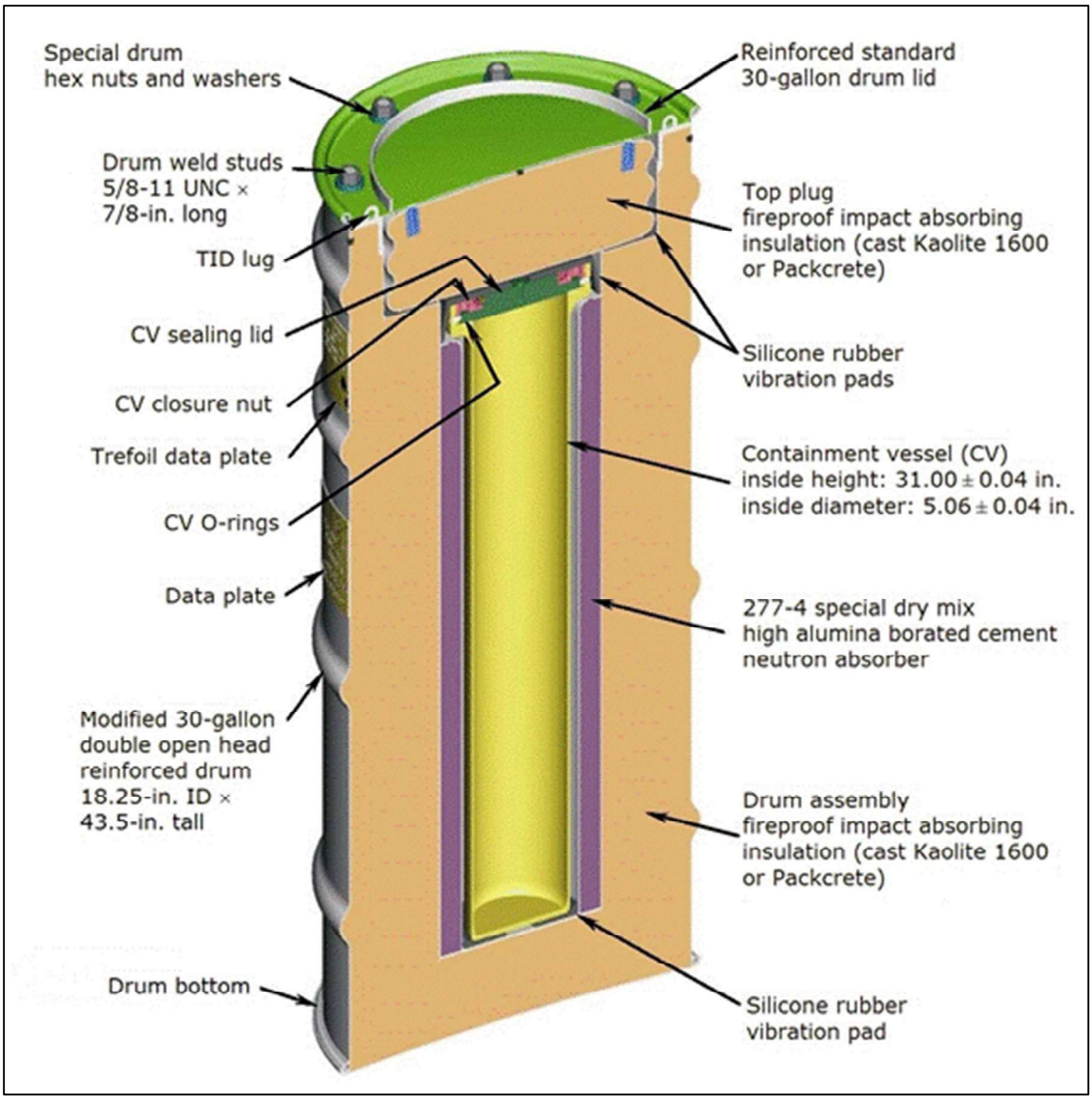

Figure 1.1. Schematic of the ES-3100 shipping package.

The CV is placed inside the outer drum assembly, surrounded by the neutron-attenuating and the impact-absorbing and thermal-insulating materials. It is approximately 32 in. (82 cm) in overall height and 5 in. (13 cm) in overall diameter, and is constructed of Type 304L stainless steel. The lid assembly consists of a sealing lid; a closure nut; an external retaining ring that holds both the assembly and closure nut together; and double O-rings. The O-rings are ethylene propylene diene monomer (EPDM) fabricated to ASTM D 2000, M3BA712A14B13F17. The double O-rings in the top flange of the CV permit leak testing of the CV.

The containment boundary consists of the 0.1 in. (0.254 cm) thick CV body, the CV sealing lid assembly, and the inner O-ring.

Option to use the ARG-US radiofrequency identification (RFID) system: The option to use the ARG-US RFID system is authorized. The RFID guide, ANL/DIS-09-5 is incorporated by reference is SARP Chapter 7 and provides procedures for using the ARG-US RFID system. The ARG-US RFID tag is not considered a part of the package. The ARG-US RFID tag is equipped with a suite of sensors to monitor seal integrity, temperature, humidity, shock, radiation, and battery status. The seal sensor is a thin, flexible membrane that is pressed by washers when installed on one of the bolts used to close the lid of the 30-gallon drum. The seal sensor may be credited as a Tamper-Indicating Device (TID) for enhanced security and safeguards, and the seal has been evaluated, and judged to be adequate, following the NRC Regulatory Guide 5.80 "Pressure Sensitive (PS) and Tamper Indicating Device Seals for Material Control and Accounting (MC&A) of Special Nuclear Material," dated December 2010. Therefore, the ARG-US RFID tag may be used as TID seal, based on "DOE Packaging Certification Program Qualification/Accreditation of ARG-US Tag as TID Seal," dated July 30, 2012. The ARG-US RFID tag has a robust plastic front cover and the stainless-steel back plate which provide adequate protection of the tag against damage under normal handling and transport. The tag weighs approximately 2.4 lb (with four batteries) and is approximately 8 in.ches wide x 7 inches high x 1.5 inches tall. Appendix B of the RFID guide provides documentation that the batteries used in the ARG-US RFID tag are not subject to the hazardous material regulations and also contains the Material/Product Safety Data Sheet for the batteries.

(3) Drawings:

The drawings that define the ES-3100 package design are listed in Table 1.0.

Table 1.0. Package Design Drawings

Drawing No.	Revision	Title
M2E801580A037	J	Consolidated Assembly Drawing (3 sheets)
M2E801580A001	D	Drum Assembly
M2E801580A002	C	Body Weldment
M2E801580A003	B	Inner Liner Weldment (2 sheets)
M2E801580A004	C	Double Open Head Reinforced Drum
M2E801580A005	E	Misc. Details
M2E801580A006	B	Drum Lid Weldment
M2E801580A007	B	18.25" Diameter Drum Lid
M2E801580A008	D	Top Plug Weldment
M2E801580A009	D	Pad Details
M2E801580A010	G	Data Plate Details
M2E801580A011	H	Containment Vessel Assembly
M2E801580A012	D	Containment Vessel Body Assembly (2 sheets)
M2E801580A013	D	Containment Vessel O-ring Details
M2E801580A014	C	Containment Vessel Lid Assembly
M2E801580A015	C	Containment Vessel Sealing Lid
M2E801580A016	B	Containment Vessel Closure Nut
M2E801580A023	E	Containment Vessel Leak Test Assemblies
M2E801580A024	D	Containment Vessel Vibration Absorbing Silicone 4.25" Can Pad
M2E801580A031	G	Main Assembly
M2E801580A043	C	Heavy Can Spacer Assembly (SST)
T2E801827A008	A	Leak Check Flange Assembly

(b) Contents

The authorized contents for shipment in the ES-3100 package consist of bulk highly enriched uranium (HEU) in the form of oxide [UO_2, UO_3, U_3O_8, U_3O_8-Al, UO_2-Mg, and product oxides (UO_2, UO_3, U_3O_8) mixed with ThO_2, ZrO_2, and Th metal]; uranium metal and alloy in the form of solid geometric shapes or broken pieces; uranium compounds; uranyl nitrate crystals (UNX); research reactor fuel elements and components.

Depleted Uranium (DU) samples or HEU metal or alloy may be shipped in tin-plated carbon steel, stainless steel, aluminum, or nickel-alloy convenience cans; Teflon convenience bottles; or Teflon bottles inside metal convenience cans. Solid form HEU contents (i.e., cylinders, bars, slugs) that will not fit in a convenience can may be bagged with no convenience can required around the contents. HEU oxide and compounds may be shipped in tin-plated carbon steel, stainless steel, or nickel-alloy convenience cans; polyethylene or Teflon convenience bottles; or glass (UO_2-Mg oxide only), polyethylene, or Teflon bottles inside metal convenience cans.

The maximum content decay heat load shall not exceed 5.0 watts.

The radioactive materials are placed in convenience cans, polyethylene bottles, or Teflon bottles. Long fuel elements may be bagged or wrapped in polyethylene or nylon. Protective end caps may be placed over bagged contents. Typical loading of the bulk HEU into the packaging, using convenience cans is depicted in Figure 1.2 of the SARP. Typical shipping configurations inside the CV are depicted in Figure 1.4 of the SARP.

The maximum concentrations of uranium isotopes that are permitted in the ES-3100 package contents are listed in Table 1.1 and the bounding uranium isotopic concentration in oxide is listed in Table 1.2.

Table 1.1. Uranium Concentration Limits

Uranium Isotope	Limit
^{232}U	0.040 µg/gU
^{233}U	0.006 g/gU
^{234}U	0.02 g/gU
^{235}U	1.00 g/gU
^{236}U	0.40 g/gU
^{238}U	1.00 g/gU

Table 1.2. Bounding Uranium Isotopic Concentration in Oxide

Isotope	Bounding Limit
^{232}U	40 ppb
^{233}U	0.6 wt %
^{234}U	2.0 wt %
^{235}U	100.0 wt %
^{236}U	40.0 wt %

In addition to the uranium isotopes shown in Tables 1.1 and 1.2, transuranic isotopes may be present in the HEU contents, and are allowed to be transported according to the limits shown below in Table 1.2a (not in the SARP), and requirements for air transport of plutonium in §71.88.

Table 1.2a. Concentration Limits for Transuranics

Mode of Transport	^{237}Np (in All Forms)	Transuranics Other Than ^{237}Np (As Metal or Alloy)	Transuranics Other Than ^{237}Np (as Other Than Metal or Alloy)
Ground	0.0250 g/gU	800.0 µg/gU	40.0 µg/gU
Air	0.0250 g/gU	40.0 µg/gU	40.0 µg/gU

Weights and Contents Descriptions

The maximum gross shipping weight of the ES-3100 package, with any contents, is 420 lb (190.5 kg). The weight of the radioactive contents in the ES-3100 package is limited to 77.6 lb (35.2 kg). The maximum weight of all contents, including the radioactive contents, the convenience cans or bottles, can spacers, polyethylene bagging and other packing materials, is limited to 90 lb (40.82 kg). There is no minimum content weight requirement.

For contents that must be shipped with spacers (see Table 1.3), the spacers must be in accordance with Drawing M2E801580A043.

Radioactive/Fissile Constituents

The maximum number of A_2s is 4752.8 (at 70 yrs) and the maximum activity is 0.72554 TBq (at 10 yrs). The following loading limits are imposed based on the mode of transport:

a) For ground transport, fissile material loading limits for all materials except Uranyl Nitrate are presented in Table 1.3 and Uranyl Nitrate is presented in Table 1.3a. CAUTION NOTE: PLEASE READ ALL FOOTNOTES ON THESE TABLES BEFORE LOADING MATERIAL.

b) For air transport, HEU in the form of metal/alloy, HEU metal or alloy turnings, fines, or powder, research reactor fuel elements and components, HEU oxide (UO_2, UO_3, U_3O_8, U_3O_8-Al, UO_2-Mg), Product Oxides (UO_2, UO_3, U_3O_8 mixed with ThO_2, Th metal, or ZrO_2), and Uranium Compounds, the fissile material mass loading limits are presented in Table 1.3b. CAUTION NOTE: PLEASE READ ALL FOOTNOTES ON THIS TABLE BEFORE LOADING MATERIAL.

c) The loading limit for mixed-mode transport is taken as the most restrictive limit for either ground or air mode of transportation (Table 1.3 or 1.3b).

Table 1.3 –Authorized Content and Fissile Mass Loading Limits for Ground Transportation [a, b, c]

Content Description		Enrichment	CSI	No Spacers, ^{235}U (kg)	277-4 can Spacers,[d] ^{235}U (kg)
Solid HEU metal or alloy (specified geometric shape) [e]	Cylinder A	≤ 100%	0.0	15.000	25.000
	Cylinder B	≤ 100%	0.0	18.000	30.000
	Cylinder C	≤ 93.5%	0.0	11.991	-
	Cylinder D	≤ 93.5%	0.0	14.656	-
	Square bars	≤ 100%	0.0	30.000	35.200 [f]
	Slugs	≤ 95%	0.0	17.374	-
	Slugs	≤ 80%	0.0	-	29.318
	Slugs	> 80%, ≤ 95%	0.0	-	24.324
	Slugs	> 80%, ≤ 95%	0.4	-	34.749
Broken HEU metal or alloy		> 95%, ≤ 100%	0.0	2.600	3.600
			0.4	4.000	5.900
			0.8	6.200	10.500
			2.0	10.700	17.500
			3.2	19.100	22.400
		> 90%, ≤ 95%	0.0	2.755	3.800
			0.4	4.370	6.395
			0.8	7.315	12.825
			2.0	13.300	21.280
			3.2	23.370	23.370
		> 80%, ≤ 90%	0.0	2.880	4.140
			0.4	4.860	8.460
			0.8	8.550	15.660
			2.0	16.110	24.750
			3.2	26.100	27.990
		> 70%, ≤ 80%	0.0	3.200	4.880
			0.4	5.840	11.040
			0.8	11.360	20.480
			2.0	20.320	28.800
			3.2	28.800	28.800
		> 60%, ≤ 70%	0.0	3.570	6.580
			0.4	7.350	15.260
			0.8	15.260	24.780
			2.0	25.200	25.200
			3.2	25.200	25.200
		≤ 60%	0.0	7.200 kg U	14.100 kg U
			0.4	17.300 kg U	32.900 kg U
			0.8	34.500 kg U	35.20 kg U [f]
			2.0	35.20 kg U [f]	35.20 kg U [f]
			3.2	35.20 kg U [f]	35.20 kg U [f]

Table 1.3 –Authorized Content and Fissile Mass Loading Limits for Ground Transportation (cont) [a, b, c]

Content Description	Enrichment	CSI	No Spacers, ^{235}U (kg)	277-4 can Spacers,[d] ^{235}U (kg)
HEU metal or alloy turnings, fines, or powders [g]	> 95%, ≤ 100%	0.0	2.600	Spacers not required
		0.4	4.000	
		0.8	6.200	
		2.0	10.500	
		3.2	10.500	
	> 90%, ≤ 95%	0.0	2.755	
		0.4	4.370	
		0.8	7.315	
		2.0	13.300	
		3.2	15.295	
	> 80%, ≤ 90%	0.0	2.880	
		0.4	4.860	
		0.8	8.550	
		2.0	16.110	
		3.2	19.800	
	> 70%, ≤ 80%	0.0	3.200	
		0.4	5.840	
		0.8	11.360	
		2.0	20.320	
		3.2	26.400	
	> 60%, ≤ 70%	0.0	3.570	
		0.4	7.350	
		0.8	15.260	
		2.0	25.200	
		3.2	25.200	
	≤ 60%	0.0	7.200 kg U	
		0.4	17.300 kg U	
		0.8	34.500 kg U	
		2.0	35.20 kg U [f]	
		3.2	35.20 kg U [f]	

Table 1.3 –Authorized Content and Fissile Mass Loading Limits for Ground Transportation (cont) [a, b, c]

Content Description		Enrichment	CSI	No Spacers, ^{235}U (kg)	277-4 can Spacers,[d] ^{235}U (kg)
HEU oxide: [h, i]		-	-	-	-
UO_2, UO_3, U_3O_8, U_3O_8-Al, UO_2-Mg,[j]		≤ 100%	See below	15.13 kg oxide	Spacers not required
Bulk Density	2.0 – 6.54 g/cm³		0.0	9.682 kg ^{235}U	
	2.0 – 6.54 g/cm³		0.4	12.323 kg ^{235}U	
	≥ 1.75, < 2.0 g/cm³		0.0	9.462 kg ^{235}U	
	≥ 1.5, < 1.75 g/cm³		0.0	8.362 kg ^{235}U	
	≥ 1.25, < 1.5 g/cm³		0.0	7.042 kg ^{235}U	
	≥ 1.0, < 1.25 g/cm³		0.0	5.941 kg ^{235}U	
	≥ 0.75, < 1.0 g/cm³		0.0	4.841 kg ^{235}U	
	≥ 0.5, < 0.75 g/cm³		0.0	3.521 kg ^{235}U	
Product oxides: UO_2, UO_3, U_3O_8 mixed with ThO_2 or mixed with Th metal		≤ 100%	See below	15.13 kg oxide	Spacers not required
Bulk Density	2.0 – 6.54 g/cm³		0.0	9.682 kg ^{235}U	
	2.0 – 6.54 g/cm³		0.4	12.323 kg ^{235}U	
	≥ 1.75, < 2.0 g/cm³		0.0	8.890 kg ^{235}U	
	≥ 1.5, < 1.75 g/cm³		0.0	6.821 kg ^{235}U	
	≥ 1.25, < 1.5 g/cm³		0.0	5.765 kg ^{235}U	
	≥ 1.0, < 1.25 g/cm³		0.0	4.841 kg ^{235}U	
	≥ 0.75, < 1.0 g/cm³		0.0	4.049 kg ^{235}U	
	≥ 0.5, < 0.75 g/cm³		0.0	3.301 kg ^{235}U	
Product oxides: UO_2, UO_3, U_3O_8 mixed with ZrO_2		≤ 100%	See below	15.13 kg oxide	Spacers not required
Bulk Density	2.0 – 6.54 g/cm³		0.0	9.682 kg ^{235}U	
	2.0 – 6.54 g/cm³		0.4	12.323 kg ^{235}U	
	≥ 1.75, < 2.0 g/cm³		0.0	8.406 kg ^{235}U	
	≥ 1.5, < 1.75 g/cm³		0.0	6.073 kg ^{235}U	
	≥ 1.25, < 1.5 g/cm³		0.0	5.105 kg ^{235}U	
	≥ 1.0, < 1.25 g/cm³		0.0	4.313 kg ^{235}U	
	≥ 0.75, < 1.0 g/cm³		0.0	3.609 kg ^{235}U	
	≥ 0.5, < 0.75 g/cm³		0.0	3.081 kg ^{235}U	

Table 1.3 –Authorized Content and Fissile Mass Loading Limits for Ground Transportation (cont) [a, b, c]

Content Description		Enrichment	CSI	No Spacers, ^{235}U (kg)	277-4 can Spacers,[d] ^{235}U (kg)
Research reactor fuel elements and components	$UZrH_X$ (TRIGA) [k]	≤ 20%	0.0	0.921 [l]	Spacers not required
		> 20%, ≤ 70%	0.0	0.408 [l]	
	$UZrH_X$ (SNAP) [k]	≥ 93%	0.0	0.857 [l]	
	U-Zr	≤ 100%	varies	See limit for broken metal or alloy	Spacers as required
	U-Al	≤ 100%	0.0	7.333 kg U-Al 1.117 kg U 1.050 kg ^{235}U	Spacers not required
	U_3O_8-Al	≤ 100%	0.0	15.13 kg oxide 9.682 kg ^{235}U	
			0.4	15.13 kg oxide 12.323 kg ^{235}U	
	UO_2	≤ 100%	0.0	21.937 kg UO_2 19.308 kg ^{235}U	
	UO_2-ThO_2	≤ 100%	0.0	21.937 kg UO_2 19.308 kg ^{235}U	
	Oxides of U-Zr [m]	≤ 100%	0.0	15.13 kg oxide 9.682 kg ^{235}	
			0.4	15.13 kg oxide 12.323 kg ^{235}U	
	UO_2-Mg	≤ 100%	0.0	15.13 kg oxide 9.682 kg ^{235}U	
			0.4	15.13 kg oxide 12.323 kg ^{235}U	
	U_3Si_2-Al	≤ 100%	0.0	5.825 kg U_3Si_2-Al 2.277 kg U 450 g ^{235}U	
Uranium compounds	UF_4	≤ 100%	0.0	3.0 kg UF_4 2.267 kg ^{235}U	Spacers not required
			2.0	24.0 kg UF_4 18.136 kg ^{235}U	
	UO_2F_2	≤ 100%	0.0	3.0 kg UO_2F_2 2.067 kg ^{235}U	
	UC	≤ 100%	0.0	2.0 kg UC 1.815 kg ^{235}U	
	UN	≤ 100%	0.0	2.0 kg UN 1.888 kg ^{235}U	
	TRISO	≤ 100%	0.0	2.0 kg TRISO 1.815 kg ^{235}U	
	U_3Si_2, U_3Si_2-Al [n]	≥ 19.7%, < 40%	0.0	13.0 kg U_3Si_2 4.819 kg ^{235}U	
		≥ 40%, ≤ 60%	0.0	7.0 kg U_3Si_2 3.892 kg ^{235}U	
	U_3Si, U_3Si-Al [n]	≥ 19.7%, < 40%	0.0	14.0 kg U_3Si 5.387 kg ^{235}U	
		≥ 40%, ≤ 60%	0.0	8.5 kg U_3Si 4.906 kg ^{235}U	

Table 1.3 –Notes:

a With the exception of the UNX crystals (Section 1.2.2.2 of the SARP), which are loaded for shipment in crystalline solid form, HEU in solution form is not authorized for shipment in the ES-3100.
b All limits are expressed in kg ^{235}U unless otherwise indicated.
c Mass loadings cannot be rounded up.
d 277-4 can spacers as described on Drawing M2E801580A043 (Appendix 1.3.7 of the SARP).
e HEU bulk metal and alloy not covered by these specific geometric shapes must be put into the broken metal category. Geometries of solid shapes are as follows:
- Cylinder A is larger than 3.24 in. diameter but no larger than 4.25 in. diameter: maximum of 1 cylinder per can.
- Cylinder B is no larger than 3.24 in. diameter: maximum of 1 cylinder per can.
- Cylinder C is a uranium-molybdenum alloy with ≤ 95 wt. % uranium and ≤ 93.5% ^{235}U enrichment; the cylinder length is ≤ 3.30 in. with an inner diam of ≥ 1.50 in., an outer diam of ≤ 4.35 in., and a maximum mass of 13.5 kg: maximum of 1 cylinder per CV.
- Cylinder D is a uranium-molybdenum alloy with ≤ 95 wt % uranium and ≤ 93.5% ^{235}U enrichment; the cylinder length is ≤ 5.80 in. with an inner diam of ≥ 1.35 in., an outer diam of ≤ 3.86 in., and a maximum mass of 16.5 kg: maximum of 1 cylinder per CV.
- Square bars are no larger than 2.29 in. × 2.29 in. (cross section): maximum of 1 bar per can.
- Slugs are a maximum of 1.5 in. diameter × 2.0 in. tall: a maximum of 10 per convenience can where the actual number permitted is restricted by the stated loading limit.

f Maximum planned content weight is 35.20 kg. Maximum analyzed content weight for criticality safety is 36.0 kg.
g Samples and small quantities ≤ 50 g of HEU metal or alloy turnings, fines, or powders may be shipped under the parent form mass limits (e.g., broken metal, reactor fuel, etc.).
h Seal time must be 12 months or less. Seal time is the length of time after the ES-3100 containment vessel is sealed that the shipment must be complete.
i Allowable HEU bulk oxide densities are 0.5-6.54 g/cm^3 and the total mass of oxide in all cases is limited to 15.13 kg. Moisture content in oxide is limited to 3 weight percent water.
j UO_2-Mg will be shipped in a glass bottle inside a metal convenience can under an inert cover gas.
k For SNAP $UZrH_x$, $x \leq 2$. For TRIGA $UZrH_x$, $x \leq 1.6$. Carbon coating for reactor fuel is not controlled (SARP Sect. 6.9.8.3.1).
l Evaluation limit is based on specific fuel type as opposed to a maximum calculated limit for $UZrH_x$.
m Oxides of U-Zr are UO_2-Zr and UO_2-ZrO_2.
n No control on the amount of aluminum.

Table 1.3a – Loading Limits for Uranyl Nitrate Crystals for Ground Transport

Product [a, b]	Seal time [c] (months)	CSI	Loading limit [d, e] (kg UNX)	U content [f] (wt%)
UNX 0 < X ≤3	2	0.4	11.90	52 < U ≤ 61
	4	0.4	6.70	52 < U ≤ 61
UNX X>3	2	0.4	9.17	46 < U ≤ 52
	4	0.0	4.75	46 < U ≤ 52

Table 1.3a Notes:

a UNX is uranyl nitrate hydrate [$UO_2(NO_3)_2 * XH_2O$] where $0 < X \leq 6$.
b Must be shipped in Teflon bottles.
c Seal Time – length of time after the ES-3100 containment vessel is sealed that the shipment must be complete.
d Total mass of UNX crystals. Spacers are not required for this content type.
e Loading limits for uranyl nitrate crystals are based on hydrogen generation calculations presented in Appendix 3.5.4 of the SARP.
f Enrichment up to 100%.

Table 1.3b - Loading Limits for Air Transport [a, b, c]

Content description		Enrichment	CSI	^{235}U (kg)
HEU metal or alloy		≤ 100%	— [d]	7.00
HEU metal or alloy turnings, fines, or powder [e]		≤ 100%	— [d]	7.00
Research reactor fuel elements and components [k] ($UZrH_X$, [f] U-Zr, U-Al, U_3O_8-Al, UO_2, UO_2-ThO_2, oxides of U-Zr,[g] UO_2-Mg,U_3Si_2-Al)		≤ 20%	— [d]	0.921
		> 20%	— [d]	0.408
HEU oxide [h, i]:		--	-	-
UO_2, UO_3, U_3O_8, U_3O_8-Al, UO_2-Mg,[j]		≤ 100%	— [d]	
Bulk density	≥ 1.0, < 1.5 g/cm³			2.15
	≥ 1.5, < 2.0 g/cm³			2.77
	≥ 2.0, < 3.0 g/cm³			3.38
	≥ 3.0, < 4.0 g/cm³			4.75
	≥ 4.0, < 5.0 g/cm³			6.02
	≥ 5.0, ≤ 6.54 g/cm³			7.57
Product oxides (UO_2, UO_3, U_3O_8) mixed with ThO_2:		≤ 100%	— [d]	see below
Bulk Density	≥ 1.0, < 1.5 g/cm³			1.14
	≥ 1.5, < 2.0 g/cm³			1.58
	≥ 2.0, < 3.0 g/cm³			2.46
	≥ 3.0, < 4.0 g/cm³			4.48
	≥ 4.0, < 5.0 g/cm³			6.02
	≥ 5.0, ≤ 6.54 g/cm³			7.57
Product oxides (UO_2, UO_3, U_3O_8) mixed with ZrO_2:		≤ 100%	— [d]	see below
Bulk Density	≥ 1.0, < 1.5 g/cm³			0.70
	≥ 1.5, < 2.0 g/cm³			0.83
	≥ 2.0, < 3.0 g/cm³			1.49
	≥ 3.0, < 4.0 g/cm³			3.12
	≥ 4.0, < 5.0 g/cm³			6.02
	≥ 5.0, ≤ 6.54 g/cm³			7.57
Product oxides (UO_2, UO_3, U_3O_8) mixed with Th metal:		≤ 100%	— [d]	see below
Bulk Density	≥ 1.0, < 1.5 g/cm³			1.18
	≥ 1.5, < 2.0 g/cm³			1.71
	≥ 2.0, < 3.0 g/cm³			2.55
	≥ 3.0, < 4.0 g/cm³			4.66
	≥ 4.0, < 5.0 g/cm³			6.02
	≥ 5.0, ≤ 6.54 g/cm³			7.57

Table 1.3b - Loading Limits for Air Transport [a, b, c] (cont.)

Content description	Enrichment	CSI	^{235}U (kg)
Uranium compounds [l]:	≤ 100%	— [d]	see below
UF_4			24.0 kg UF_4 18.13 kg ^{235}U
UO_2F_2	≤ 100%	— [d]	3.0 kg UO_2F_2 2.06 kg ^{235}U
UC	≤ 100%	— [d]	2.0 kg UC 1.81 kg ^{235}U
UN	≤ 100%	— [d]	2.0 kg UN 1.88 kg ^{235}U
U_3Si_2	≥ 19.7%, < 40%	— [d]	8.5 kg U_3Si_2 3.15 kg ^{235}U
	≥ 40%, ≤ 60%		6.5 kg U_3Si_2 3.61 kg ^{235}U
U_3Si	≥ 19.7%, < 40%	— [d]	8.5 kg U_3Si 3.27 kg ^{235}U
	≥ 40%, ≤ 60%		6.5 kg U_3Si 3.75 kg ^{235}U

Table 1.3b Notes:

a All limits are expressed in kg ^{235}U unless otherwise indicated.
b Mass loadings cannot be rounded up.
c The loading limit for mixed-mode transport is taken as the most restrictive limit for either ground or air mode of transportation (Table 1.3 or 1.3b of SARP and this certificate).
d. CSI and spacer use are governed by ground transport mode.
e. If the mass of metal or alloy turnings, fines, or powders is ≤ 50 grams, then it may be shipped as the parent form (e.g., broken metal, reactor fuel, etc.).
f. For SNAP $UZrH_x$, $x \leq 2$. For TRIGA $UZrH_x$, $x \leq 1.6$.
g. Oxides of U-Zr are UO_2-Zr and UO_2-ZrO_2.
h Seal time must be 12 months or less. Seal time is the length of time after the ES-3100 containment vessel is sealed that the shipment is complete.
i Allowable HEU bulk oxide densities are 1.0-6.54 g/cm^3. Moisture content in oxide is limited to 3 weight percent water.
j UO_2-Mg will be shipped in a glass bottle inside a metal convenience can under an inert cover gas.
k Carbon coating for reactor fuel is not controlled (SARP Sect. 6.9.8.3.1).
l Allowable uranium compound bulk densities are 2.0–6.54 g/cm^3.

(c) Criticality Safety Index

The Criticality Safety Index (CSI) assigned for each content is shown above in section 5(b) of this certificate.

(d) Conditions

(1) The vent holes on the outer steel drum shall be capped closed during transport and storage to preclude entry of rain water into the insulation cavity of the drum.

(2) Content forms may not be mixed in a single ES-3100 containment vessel.

(3) Where can spacers are required for a “per package” mass loading, the quantity of fissile materials located in any vacancy between or adjacent to can spacers shall not exceed one-third of the mass loading limit in Table 1.3. Spacers must be positioned between every two convenience cans, or in

the case of shipping one convenience can only, the spacer must be positioned on top of the single can.

(4) Uranium metal and alloy pieces must have a surface-area-to-mass ratio of not greater than 1.00 cm^2/g or must not pass freely through a 3/8-inch (9.5 mm) mesh sieve, or equivalent size-grading system. The uranium metal must also have had no more than a limited contact with water and been subsequently dried. Particles and small shapes that do not pass this size restriction, as well as powders, foils, turnings, and wires, are not permitted, unless they are in a sealed container under an inert cover gas. Uranium material or alloy which has been stored in water or is visibly wet at the time of packaging is not authorized to be shipped in this package.

(5) Intact TRIGA fuel elements and fuel section elements (pellets) are allowed. Fuel from TRIGA reactor elements shall be unirradiated. The fuel sections may be from any of three types of fuel elements: TRIGA standard fuel elements, instrumented TRIGA standard fuel elements, and TRIGA fuel follower control rods. The ^{235}U mass for TRIGA standard fuel elements and instrumented TRIGA standard fuel elements is a nominal 136 grams per element, and the ^{235}U mass for TRIGA fuel follower control rods is a nominal 113 grams per element. Each fuel element contains three fuel sections, either stainless steel or aluminum clad or unclad. The fuel elements are approximately 15 inches in length, with sections approximately 5 inches in length; the approximate diameter of the fuel is 1.44 inches for the standard and instrumented fuel elements, and 1.31 inches for the fuel follower control rods. The fuel elements and sections are packaged within stainless steel or tin-plated carbon steel convenience cans. Disassembled fuel elements are to be packaged with a maximum of three fuel sections, or three fuel elements, per convenience can. Fuel sections from different fuel elements may not be mixed within a single convenience can. A maximum of three convenience cans with disassembled fuel elements may be loaded into a single package. Three stainless steel or aluminum clad elements with crimped ends are to be packaged in a single convenience can with a maximum of one can per package. For TRIGA standard fuel elements and instrumented TRIGA standard fuel elements, the maximum allowable loading per package is 408 grams ^{235}U per package, and for TRIGA fuel follower control rods, the maximum allowable loading is 339 grams ^{235}U per package.

The SNAP fuel pins are approximately 1.25 inches in diameter and approximately 12.45 inches long. The SNAP fuel pins may be packed in appropriate length convenience cans or bundled together and protected on each end with an open-ended can. A maximum of three SNAP fuel elements may be packed into any one convenience can or any one bundle. Up to two loaded convenience cans or two bundles may be shipped in the ES-3100.

(6) Any combination of convenience can sizes is allowed in a single package, as long as the total height of the can stack (including silicone rubber pads and spacers, if required) does not exceed the inside working height of the containment vessel (31 inches). Any closure on the convenience can is allowed.

(7) The maximum mass of off-gassing packing materials in the containment vessel (e.g., polyethylene containers or bagging, silicone rubber pads, nylon bags, etc.) shall not exceed 500 grams. Off-gassing packing materials may be any type of hydrogenous material, except in the case of shipping uranium in the form of broken metal, in which case the hydrogenous material must have a hydrogen atom density less than or equal to that of water. With the use of Teflon bottles as convenience containers, the maximum mass of off-gassing packaging material may be increased by approximately 330 grams for Teflon only, for each Teflon bottle; up to three Teflon bottles (990 grams of Teflon) and off-gassing packaging material (500 grams max.) are permitted in the containment vessel (1,490 grams/package). If closed convenience cans with an outer diameter greater than 4.25 inches are used, the user shall verify at least 43 cubic inches of free or void volume must exist inside the containment vessel to allow for gas expansion and offgassing of packing materials at temperatures associated with NCT or HAC.

(8) Empty convenience cans, spacers, silicone rubber pads, and/or stainless-steel scrubbers (i.e., stainless steel trimmings that act as dunnage) may be used to fill the void space in the

containment vessel. In situations where empty convenience cans are shipped in the package, they may be placed either above or below the loaded cans. Empty convenience cans must have a minimum 0.125 inches diameter hole through the lid.

(9) The contents and the convenience cans may be bagged or wrapped in polyethylene, nylon, Teflon, or aluminum foil for contamination control provided the limits of Section 5(d)(7) of this certificate are met.

(10) The mass of unidentified constituents in the content to be shipped shall be counted against the fissile mass loading limit. Content shall not contain unevaluated moderating materials.

(11) Transport by air is not authorized, except as specified in Table 1.3b. For air transport, the total amount of free water in the package is limited to 12 lb (5,443 g), which is water absorbed in the encapsulated Kaolite or Packcrete. Other than that, the ES-3100 package will not contain any free water at the time it is loaded for transport.

(12) In addition to the requirements of Subparts G and H of 10 CFR Part 71, and except as specified in section 5(d) of this certificate, each package must be fabricated, acceptance tested, operated, and maintained in accordance with the Operating Procedures requirements of Chapter 7, Acceptance Tests and Maintenance requirements of Chapter 8, and packaging-specific Quality Assurance requirements of Chapter 9 of SARP, Revision 3, as supplemented.

(13) Revision 18 of the certificate may be used until November 30, 2023. For export or import use of this package under a Department of Transportation Competent Authority Certification (CAC), previous revisions of the CAC may continue to be used until their expiration date, unless otherwise specified in the CAC.

(14) The periodic leakage rate test interval of the containment boundary is 24 months.

(15) Only use the drawings listed in 5(a)(3) of this certificate.

(16) Transport by air or ground is authorized for HEU metal or alloy turnings, fines, or powders in the ES-3100 package. These contents shall be in a sealed inerted container: the Teflon bottles, the metal convenience cans, and the containment vessel shall be inerted with argon of high purity (> 99%) and with low moisture (< 5 ppm moisture).

(17) Only Departmental elements or persons working under contract to Departmental elements shall consign the package for shipment.

(18) Nuclear Regulatory Commission (NRC) or Agreement State licensees shall not consign a DOE certified package for shipment, but can transfer the material on-site to DOE elements or persons working under contract to DOE elements for consignment of the package.

(19) HEU oxide with residual particles of metallic uranium (a.k.a., clinkers and screenings) and meeting the requirements of footnote “i” of Table 1.3 (for ground transport) or Table 1.3b (for air transport) of this certificate must be prepared for shipment in accordance with the authorized content and loading limits for “Broken HEU metal or alloy” in Table 1.3 (for ground transport) or Table 1.3b (for air transport) and Condition (4) of this certificate, and must be shipped within the seal time per footnote “h” of the aforementioned tables.

(20) Notwithstanding Drawings M2E801580A011 Revision H and M2E801580A012 Revision D, the change in M2E801580A011 for “Company Approved Equal” is not authorized for the CV body assembly, which is a Quality Category A component (SARP Table 9.2), and the change in M2E801580A012 to allow machining the CV body from a solid billet of stainless steel is not evaluated in the SARP and therefore is not authorized.

(21) The package is authorized for air transport, in accordance with 49 CFR 173.418(e), of a limited quantity ($\leq 10^{-3}$ A_2 mixture per package) of normal form solid DU samples in the form of metal or alloy turnings, fines, or powders, with a fissile mass ≤ 2 grams per package (i.e., fissile excepted). These contents shall be in a sealed inerted container: the Teflon bottles, the metal convenience cans, and the containment vessel shall be inerted with argon of high purity (> 99%) and with low moisture (< 5 ppm moisture). SARP Package Operations for HEU material are applicable for DU.

(e) Supplements

(1) *ES-3100 Depleted Uranium Usage*, RP 801580-0032 000 01, December 2021.

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U.S. Department of
Transportation

**Pipeline and
Hazardous Materials
Safety Administration**

CERTIFICATE NUMBER: USA/9315/B(U)F-96

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