BWXT Y-12

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

Revised SAR pages associated with Amendment #1 for the Model ES-3100 Shipping Container, Docket No. 71-9315, USA/9315/B(U)F-96

A telephone conference between the Nuclear Regulatory Commission and the Department of Energy was conducted on July 12, 2006, to discuss the content of the reference Amendment #1. During the course of the call, the NRC identified an inconsistency between the wording in the Certificate of Compliance (CoC), Revision 0, [USA/9315/B(U)F-96] and wording in the ES-3100 Safety Analysis Report (SAR).

The specific inconsistency was in the definition of pyrophoric uranium as it relates to broken metal contents. In the CoC, the definition is given in paragraph 5.(b)(1)(ii) and in the SAR the definition is given on the top of page 1-12. The inconsistency occurred because the pyrophoric definition in the final change pages of the SAR (before the CoC was issued) was not accepted by the NRC, instead the definition in the original SAR issue was accepted. So, by this action, the wording in the SAR has been made consistent with the wording in the CoC. The pyrophoric definition also appears on SAR pages 2-26 and 6-23, and those two instances have also been revised to be consistent with the CoC. These three revised SAR pages are attached.

Also noted during the telephone conference was a typo in Table 3.10 on page 3-15 of the SAR. The value of P_T for CVA 6 was incorrectly given. That table entry has been corrected and a revised page 3-15 is attached.

NMSS01

If you have any questions regarding this submittal, please contact me at (865) 241-3854 or Jeff Arbital at (865) 576-8254.

Sincerely yours,

George B. Singleton

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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 the ES-3100 convenience cans.

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 and alloy pieces must have a surface-area-to-mass ratio of not greater than 1 cm^2/g or must have a mass not less than 50 g, whichever is most restrictive.

2. Incidental small particles and samples (those which do not pass the size restriction tests in #1) including foils, turnings, or wires are not permitted, unless they are restricted to not more than 1 percent by weight of the content per convenience container, and they are either in a sealed, inerted container or are stabilized to an oxide prior to shipment.

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 2.17. Mechanical properties of the cast neutron absorber

Material		Cat 277-4
Service temperature range, °C (°F)		−40 to 150 (−40 to 302)
Modulus of elasticity in tension, GPa (Mpsi) at temperatures [a]		
	−40°C (−40°F)	13.72 (1.991)
	21.11°C (70°F)	4.72 (0.684)
	37.78°C (100°F)	2.78 (0.403)
Coefficient of thermal expansion, cm/cm/°C (in./in./°F) at temperatures [b]		
	−40°C (−40°F)	12.700×10^{-6} (7.056×10^{-6})
	−20°C (−4°F)	13.000×10^{-6} (7.222×10^{-6})
	0°C (32°F)	13.000×10^{-6} (7.222×10^{-6})
	40°C (104°F)	12.600×10^{-6} (7.000×10^{-6})
	60°C (140°F)	11.599×10^{-6} (6.444×10^{-6})
	80°C (176°F)	10.400×10^{-6} (5.778×10^{-6})
	100°C (212°F)	9.700×10^{-6} (5.389×10^{-6})
	120°C (248°F)	9.101×10^{-6} (5.056×10^{-6})
Poisson Ratio		
	−40°C (−40°F)	0.33 [a]
	21.11°C (70°F)	0.28
	37.78°C (100°F)	0.25
Density, g/cm³ (lb/in.³)		1.682 (0.0608)

[a] *Mechanical Properties of 277-4* (Appendix 2.10.4).
[b] *Thermophysical Properties of Heat Resistant Shielding Material* (Appendix 2.10.4).

Analysis. Starting with the outer components, the packaging consists of the drum (austenitic type 304 stainless steel), weld studs (austenitic stainless steel), nuts (silicon bronze), insulation (cast refractory), neutron absorber (Cat 277-4), silicone support pads, containment vessel (austenitic type 304L stainless steel), closure nut (Nitronic 60), silicone support pads, can spacers (stainless steel and Cat 277-4), stainless-steel scrubbers, convenience cans (stainless steel, tin-plated carbon steel, or nickel-alloy [series 200, passivated]), polyethylene bottles, polyethylene bags, and the HEU contents.

The cast refractory insulation (Kaolite) is contained between the drum and mid liner and within the top plug assembly's stainless-steel sheet metal. Due to the alkaline nature of this material, greater permanence of the surrounding structure is assured. Also, this material has been used successfully for years as an insulation heat treatment liner adjacent to metal surfaces of furnaces.

The cast neutron absorber (Cat 277-4) is contained between the inner liner and mid liner. During the casting process, the chlorine content is limited to 100 parts per million. The small quantity of chlorine will not affect the stainless-steel liners.

The nuts used to attach the drum to the lid are silicon bronze. All other metal components of the packaging are either stainless steel, Nitronic 60, or tinned steel. All stainless-steel components are passivated per ASTM A380, Paragraph 6.4, and Table A2.1, Part II. Prior to assembly, the packaging will be kept inside a building or transported between buildings in an enclosed truck. The assembled components are protected from the weather and inspected at the time of packaging; therefore, the package will not contain any free water at the time it is loaded for transport. Under NCT, the only moisture present will be the relative humidity or moisture absorbed by the cast refractory or neutron absorber materials. When the package is subjected to a water-spray type environment, some water may leak into the cavity formed by the inner liner and occupied by the containment vessel. To minimize the possibility of any potentially corrosive situation, a visual examination of the interior surface of the inner liner and the exterior surface of the containment vessel shall be conducted prior to packing and following transport of the shipping package (see Sect. 7). Any free water present and any corrosion discovered shall be promptly removed.

During immersion under HAC, water can enter the holes at the top of the drum, be absorbed into the cast refractory material, and fill all void spaces within the drum and inner liner. The insulating value of the insulation material may be decreased, and an overall weight increase would occur. The most important consideration is that the containment boundary remain intact and leaktight. This situation has been evaluated by completely immersing the containment vessel in a tank simulating 0.9-m and 15-m (3- and 50-ft) immersion depths. The containment vessel remained intact and water tight, as demonstrated by the analysis and testing discussed in Sect. 2.7.

All physical contact between the convenience cans and the containment vessel wall, bottom, or top is minimized through the use of the silicone support pads. The polyethylene bottles will be in contact with the stainless steel of the containment vessel, but will not react. All cans and bottles will provide the necessary separation of the HEU contents from the containment vessel walls. Nickel-alloy cans are galvanically similar to the stainless steel of the containment vessel and thus will not react. Additionally, polyethylene bagging may be used around the convenience container (in some cases the HEU is bagged inside the container) as required by packaging personnel. Therefore, galvanic corrosion between the containment vessel wall and convenience containers is highly unlikely. In addition, the environment inside the containment vessel is free of electrolytic solutions, further assuring there will be no galvanic reactions occurring inside the containment vessel.

For pyrophoric considerations, HEU metal pieces are restricted to a surface-area-to-mass ratio of not greater than 1 cm^2/g or must have a mass not less than 50 g, whichever is most restrictive. Incidental small particles and samples (those which do not pass the size restriction tests) including foils, turnings, or wires are not permitted, unless they are restricted to not more than 1 percent by weight of the content per convenience container, and they are either in a sealed, inerted container or are stabilized to an oxide prior to shipment.

The containment boundary remains intact even when the drum and inner liner are filled with water; therefore, the package is acceptable to the maximum credible extent from the standpoint of chemical, galvanic, or other reactions.

2.2.3 Effects of Radiation on Materials

The HEU material is not irradiated. The neutron and photon dose rates (Sect. 5) are well below those required to damage any of the package materials by radiolytic interactions.

2.3 FABRICATION AND EXAMINATION

2.3.1 Fabrication

2.3.1.1 Drum assembly fabrication

The drum assembly is fabricated in accordance with equipment specifications JS-YMN3-801580-A002 (Appendix 1.4.2), JS-YMN3-801580-A003 (Appendix 1.4.4), and JS-YMN3-801580-A005 (Appendix 1.4.5). The later two specifications control the casting of the Kaolite 1600 and Cat 277-4 materials inside the liners, spacer cans and the top plug as appropriate.

2. The convenience cans and bottles are assumed to be sealed to minimize the void volume inside the containment vessel.
3. Convenience can and bottle geometry does not change during pressure increase inside containment vessel.
4. For polyethylene bottle configurations, polyethylene bottles and bagging weight is limited to 500 g per containment vessel.
5. ~~No contents that will off-gas at temperatures about ambient temperature can be used inside the containment vessel when convenience cans are greater than 10.80 cm (4.25 in.) in diameter.~~

Table 3.10. Total pressure inside the containment vessel at 87.81°C (190.06°F) [a]

CVA	n_a (lb-mole)	n_v (lb-mole)	n_{po} (lb-mole)	n_{bo} (lb-mole)	n_T (lb-mole)	P_T (psia)
1	3.0855e-04	1.0057e-05	0.0000e+00	0.0000e+00	3.1861e-04	17.786
2	3.1264e-04	1.0190e-05	0.0000e+00	0.0000e+00	3.2283e-04	17.786
3	3.1997e-04	1.0429e-05	0.0000e+00	0.0000e+00	3.3040e-04	17.786
4	2.9252e-04	9.5344e-06	0.0000e+00	0.0000e+00	3.0205e-04	17.786
5	6.7348e-05	2.1951e-06	0.0000e+00	0.0000e+00	6.9543e-05	17.786
6	2.3215e-04	7.5666e-06	0.0000e+00	0.0000e+00	2.3972e-04	17.786

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

3.1.4.2 Maximum HAC Pressures

Table 3.11 summarizes the results from Appendix 3.6.5 in which the pressure of the containment vessel when subjected to the tests and conditions of HAC per 10 CFR 71.73 has been determined for the most restrictive CVAs shipped in the ES-3100. The shipping configurations discussed in Sect. 3.1.4.1 are evaluated for HAC. To determine the maximum pressure generated inside the ES-3100's containment vessel due to HAC conditions, the following assumptions have been used in the calculations:

1. The initial pressure inside the containment vessel is the maximum normal operating pressure shown in Table 3.10 for each CVA at ambient temperature.
2. The convenience cans and bottles are assumed to be sealed in order to minimize the void volume inside the containment vessel.
3. Convenience can and bottle geometry does not change during pressure increase inside containment vessel or because of damage from compliance testing.
4. For polyethylene bottle configurations, polyethylene bottles and bagging weight is limited to 500 g per containment vessel.
5. ~~No contents that will off-gas at temperatures about ambient temperature can be used inside the containment vessel when convenience cans are greater than 10.80 cm (4.25 in.) in diameter.~~

The above assumptions are very conservative because the convenience cans buckle and deform significantly under an external pressure differential of one atmosphere as demonstrated during the helium leak checking. When the convenience cans deform inward under external pressure, additional void volume is created, thereby reducing the overall pressure inside the containment vessel. However, quantitative data on this structural deformation of the convenience cans has not been measured, and repeatability of the deformation is not predictable. Therefore, convenience can geometry is assumed not to change for the calculation of pressure inside the containment vessel.

Table 3.11. 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	3.9060e-04	1.9225e-05	3.1529e-04	7.2512e-04	43.938
3	3.9976e-04	1.1535e-05	3.1529e-04	7.2659e-04	43.018
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~~	~~25.668~~
6	2.9004e-04	0.0000e+00	3.1529e-04	6.0533e-04	19.896

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

3.2 SUMMARY OF THERMAL PROPERTIES OF MATERIALS

3.2.1 Material properties

Thermal properties at various temperatures for the stainless steel used in the fabrication of the drum, noncombustible cast refractory (Kaolite 1600), noncombustible neutron poison (BoroBond 4 or Cat 277-4), silicone rubber pads, and air are listed in Table 3.12. Properties used to evaluate thermal stresses due to differences in coefficient of thermal expansion are listed in Table 3.13.

3.2.2 Component Specifications

Component specifications are listed in Tables 3.14 and 3.15.

3.3 GENERAL CONSIDERATIONS

Thermal evaluation of the package design for NCT was performed by analysis. Evaluation of the package design for HAC was performed by a combination of testing and analysis.

3.3.1 Evaluation by Analysis

A description of the method and calculations used to perform the thermal and thermal stress analyses of the package for NCT and HAC is presented in detail in Appendices 3.6.1, 3.6.2 and 3.6.3.

6.2.4 Package Content Loading Restrictions

Loading restrictions based upon the results of the criticality safety calculations presented in Sects. 6.4 and 6.5 are as follows:

(1) HEU fissile material to be shipped in the ES-3100 package shall be placed in stainless steel, aluminum, tin-plated carbon steel, or nickel-plated carbon steel convenience cans. The can lid types may be welded, press fit, slip lid, crimp seal, or screw cap.

(2) The ES-3100 package may carry up to six loaded convenience cans as shown on Drawing No. M2E801580A035. Configurations of convenience cans up to 5.0-in. diameter are permissible provided Cat 277-4 canned spacers are used as needed for criticality control.

(3) A shipping package may be loaded with "x" number of content-bearing convenience cans. In situations where the plan for loading the containment vessel calls for the use of empty convenience cans to fill the containment vessel, the heavier cans will be loaded into the bottom of the upright shipping container, and the empty cans will be placed above them.

(4) The presence of uranium isotopes is limited on a weight-percent basis as follows: $^{232}U \leq 40$ ppb U, $^{234}U \leq 2.0$ wt % U, $^{235}U \leq 100.0$ wt % U, and $^{236}U \leq 40.0$ wt % U.

(5) For pyrophoric considerations, HEU metal pieces are restricted to a surface-area-to-mass ratio of not greater than 1 cm^2/g or must have a mass not less than 50 g, whichever is most restrictive. Incidental small particles and samples (those which do not pass the size restriction tests) including foils, turnings, or wires are not permitted, unless they are restricted to not more than 1 percent by weight of the content per convenience container, and they are either in a sealed, inerted container or are stabilized to an oxide prior to shipment.

(6) The content shall not exceed the "per package" fissile material mass loading limits specified in Table 6.2 based on the CSI. Where can spacers are required for a "per package" mass loading, the quantity of fissile material located between any two Cat 277-4 canned spacers shall not exceed one-third of the mass loading limit. The content mass loading may be further restricted based on structural, mechanical, and practical considerations (see Sects. 1 and 2).

(7) HEU bulk metal or alloy content not covered by the specified geometric shapes (HEU sphere, stacked spheres, cylinder, square bar, or slug contents) will be in the HEU broken metal category, and so limited.

(8) The package content is defined as the HEU fissile material, the convenience cans and can spacers, and the associated packing materials (plastic bags, pads, tape, etc.) inside the ES-3100 containment vessel.

(9) The CSI is determined on the basis of the uranium enrichment and total ^{235}U mass in the package and content shape or form.

6.3 GENERAL CONSIDERATIONS

The ES-3100 packaging configuration is shown on Drawing No. M2E801580A031 (Appendix 1.4.8). KENO V.a modeling of this configuration with the maximum allowable contents (Sect. 6.2) for a variety of array sizes and array conditions yields bounding calculations that determine the package's CSI (Tables 6.1a–6.1c). Key input listings are provided in Appendix 6.9.7.

The HEU content of a package is in one of the following forms: metal of a specified geometric shape, metal of an unspecified shape characterized as broken metal, uranium oxide, or UNX crystals. The bounding types of HEU content evaluated in this criticality analysis are: 3.24-in. diameter spheres and cylinders; 2.29-in. square bars; 1.5-in. diameter × 2-in. tall slugs; cubes ranging from 0.25 to 1 in. on a side; broken metal pieces of unspecified geometric shape; uranium oxide; and UNX crystals. 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

HEU metal shapes are distributed in a optimum arrangement in the flooded containment vessel. For the single package and the array calculations, the HEU broken metal is modeled as a homogeneous mixture of uranium metal and water filling the interior of a flooded containment vessel. This representation bounds the heterogeneous configuration of metal pieces interspersed with hydrogenous packing material inside of wrapped convenience cans (Appendix 6.9.3., Sect. 6.9.3.1). Water soluble UNH crystalline content is modeled as a homogeneous mixture of uranyl nitrate and water filling the interior of the containment vessel.

No credit is taken for the fissile material spacing, neutron absorption, or free volume reduction provided by the presence of can pads, spacer can steel and convenience cans inside the containment vessel. Water is substituted for polyethylene bagging which may be in use as packing material for both the content placed inside the convenience can and the cans themselves. Pads of steel turnings rolled up into a disk-like shape may also be present in the ES-3100 package, in use as cushioning and for reducing the free volume inside the convenience cans. This steel packing material acts as a neutron absorber and is excluded from the calculation model.

The Cat 277-4 material inside the spacer can is not less than 3.95-in. in diameter by 1.06-in. in thickness. Can spacers are used as indicated in Table 6.2 for the purpose of reducing neutronic interaction between the contents of the package, aiding in maintaining $k_{eff} + 2\sigma$ for the ES-3100 package below the USL.

Criticality calculations are performed for the containment vessel under full water reflection whereby the water content inside the containment vessel is varied from dry to fully flooded conditions. These calculations demonstrate that the fully flooded condition is most reactive. The containment vessel is flooded in the single-unit calculation model and the infinite and finite array calculation models for both the NCT and HAC evaluations.

The KENO V.a models discussed in the following sections are the single-unit calculation model (Sect. 6.3.1.1), the infinite and finite array calculation models (Sect. 6.3.1.2), and the HAC calculation models (Sect. 6.3.1.3). The single-unit calculation model is evaluated with a vacuum boundary condition and with full water reflection. The finite array calculation model is evaluated in arrays consisting of packages stacked in 13×13×6, 9×9×4, 7×7×3, and 5×5×2 arrangements with full water reflection at the array boundary.

The geometry of the ES-3100 package is depicted in Drawing No. M2E801580A001 (Appendix 1.4.8). Calculation models of this geometry for evaluating NCT and HAC must be constructed for the single-unit, infinite array and finite arrays within the constraints and capabilities of KENO V.a. As shown in the drawing, the ES-3100 geometry is complex. Given KENO V.a's constraints and capabilities, two methods may be used to evaluate these complex geometries: simplify the geometries with conservative approximations or construct accurate geometries from simple components. Both methods yield valid results;