May 8, 2009

James M. Shuler
U.S. Department of Energy
EM-63, CLV-2047
1000 Independence Avenue, S.W.
Washington, DC 20585

SUBJECT: REVISION 9 OF CERTIFICATE OF COMPLIANCE NO. 9315 FOR THE MODEL NO. ES-3100

Dear Dr. Shuler:

As requested by your letter dated October 11, 2007, as supplemented March 11, 2008, June 19, 2008, August 26, 2008, September 8, 2008, and February 24, 2009, and your consolidated application dated May 7, 2009, enclosed is Certificate of Compliance (CoC) No. 9315, Revision No. 9, for the Model No. ES-3100 package. You requested various changes to your CoC in this request. Changes made to the enclosed certificate are indicated by vertical lines in the margin. The staff's Safety Evaluation Report is also enclosed.

Those on the attached list have been registered as users of the package under the general license provisions of 10 CFR 71.17 or 49 CFR 173.471. This approval constitutes authority to use the package for shipment of radioactive material and for the package to be shipped in accordance with the provisions of 49 CFR 173.471. Registered users may request, by letter, to remove their names from the Registered Users List.

If you have any questions regarding this certificate, please contact me at (301) 492-3294 or Kim Hardin of my staff at (301) 492-3339.

Sincerely,

/RA/

Eric J. Benner, Chief
Licensing Branch
Division of Spent Fuel Storage and Transportation
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-9315
TAC No. L24141
Enclosures: 1. Certificate of Compliance
No. 9315, Rev. No. 9
2. Safety Evaluation Report
3. Registered Users

cc w/encls 1 and 2: R. Boyle, Department of Transportation
Registered Users

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DATE:	5/4/09		5/7/09		5/7/09		5/5/09		5/7/09		5/6/09
OFC:	SFST		SFST		SFST		SFST		SFST		SFST
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SAFETY EVALUATION REPORT

Docket No. 71-9315
Model No. ES-3100 Package
Certificate of Compliance No. 9315
Revision No. 9

TABLE OF CONTENTS

SAFETY EVALUATION REPORT

Docket No. 71-9315
Model No. ES-3100 Package
Certificate of Compliance No. 9315
Revision No. 9

SUMMARY

By application dated October 11, 2007, as supplemented March 11, 2008, June 19, 2008, August 26, 2008, September 8, 2008, and February 24, 2009, the Department of Energy (DOE or the applicant) requested a revision to Certificate of Compliance (CoC) No. 9315 for the Model No. ES-3100 transportation package. DOE consolidated its application by letter dated May 7, 2009. DOE requested various changes to the CoC.

The approval of the various changes are to support the Naval Reactor Program and other DOE programs.

CoC No. 9315 has been amended based on the statements and representations in the application and supplements, and staff agrees that the changes do not affect the ability of the package to meet the requirements of Title 10 of the Code of Federal Regulations (10 CFR) Part 71.

EVALUATION

The submittal was evaluated against the regulatory standards in 10 CFR Part 71, including the general standards for all packages, standards for fissile material packages, and performance standards under normal conditions of transport (NCT) and hypothetical accident conditions (HAC). Staff reviewed the application using the guidance in NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material."

Based on the statements and representations in the application, as supplemented, and the conditions listed in the CoC, the staff concludes that the design has been adequately described and evaluated and meets the requirements of 10 CFR Part 71.

REFERENCES

DOE, application dated February 25, 2005.

DOE, supplements dated March 11, 2008, June 19, 2008, August 26, 2008, September 8, 2008, and February 24, 2009.

1.0 GENERAL INFORMATION

1.1 Package Description

There were no requested changes to the packaging.

1.2 Packaging Drawings

The applicant submitted one revised license drawing. The revised drawing includes:

Drawing No. M2E801580A037, Rev. C, “Consolidated Assembly Drawing”

The drawing was revised for an administrative change. The owner’s name on the data plate was changed.

1.3 Contents

The specific changes requested in this application are as follows:

- Revised criticality safety calculations and fissile loadings for all the authorized contents of the package,
- Revised Criticality Safety Index (CSI) for the ES-3100,
- Revised quantity of off-gassing material that can be transported as packing material within the ES-3100 containment vessel, including a Teflon bottle as a convenience container for the uranyl nitrate crystal,
- Revised concentration of carbon in uranium oxide shipped in the ES-3100,
- Revised concentration of the neptunium-237 in uranium shipped in the ES-3100,
- Specification of uranium alloyed with aluminum, molybdenum, and zirconium as contents of the ES-3100, and
- Revision of the manufacturing specification for the neutron absorber material (277-4).

The revision of the neutron absorber specification was completed separately in Revision 7 of CoC No. 9135 dated January 30, 2008.

2.0 STRUCTURAL

The staff reviewed the application to revise the Model No. ES-3100 package structural design and evaluation to assess whether the package will remain within the allowable values or criteria for normal conditions of transport (NCT) and hypothetical accident conditions (HAC) as required in 10 CFR Part 71. This application was also reviewed to determine whether the package fulfills the acceptance criteria listed in Section 2 (Structural Review) of NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel."

2.1 Structural Evaluation

The Staff has reviewed the ES-3100, Rev. 1, and noted that changes were made in the structural evaluation regarding content mass, internal pressure changes, as well as some material property changes. In reviewing these changes, the staff found that variations were minor and had no effect on the ability of the package to perform its safety function. The staff concludes that this package meets the requirements and intent of 10 CFR Part 71.

2.2 Materials Evaluation

Only two changes made in this amendment have materials implications:

- An increase in the amount of off-gassing material that can be transported as packing material in the ES-3100 to 1500 g, and adding a teflon bottle as a convenience can for uranyl nitrate.
- Allowing metallic uranium that had minimal contact with water as an approved content.

The materials questions arising from the request to add more packing material and using a Teflon container are:

- Will the gas released by the increased amount of out-gassing material over pressurize the canister?
- Will the off-gas from the Teflon can interact adversely with the uranyl nitrate?

Based on out-gassing experiments conducted at Oak Ridge National Laboratory, the applicant conservatively estimated an off gas for the Teflon of 0.25 cm^3/g @ standard temperature and pressure (STP) (data showed 0.1 cm^3/g @ STP for the out-gassing at 190°C and 0.15 cm^3/g @ STP for an out-gassing temperature of 263°C). These bound the out-gassing rate for the other additional requested packing materials and can be used as a bounding value in the containment analysis. Vapor pressure was based on 100% RH at the time of loading, and a sealed convenience can to minimize the volume. At the maximum normal and accident temperatures, the maximum expected pressure in the canister was 20 and 65 psia, respectively. Both of these values are below the hydrostatic test pressure given in Table 4.2 of this SER, and the out-gassing rates are acceptable.

The recommended maximum long-term operating temperature for Teflon FEP is 205°C.[1] Below this temperature thermal decomposition is not expected to occur.[2] The maximum expected temperature predicted in the Safety Analysis Report (SAR) Sec. 2.2.2 (NCT or HAC) inside the ES-3100 containment vessel at the location near the Teflon FEP bottles is 124°C. Therefore, no decomposition of the Teflon vessel is expected and no corrosive atmosphere will be available to interact with the uranyl nitrate crystals. The staff finds no materials issues with this request.

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[1] Zeus – Introduction to Fluoropolymers www.zeuinc.com
[2] Leidecker, Henning "Thermal decomposition of Teflon"
misspiggy.gsfc.nasa.gov/tva/issfoc/iss/docs/Henning**FEP**.doc

The current CoC does not allow the shipment of uranium metallic particulate that has been in contact with, or stored in water. The applicant has requested that uranium metal shavings that were in contact with water for a limited time and then dried be allowed as acceptable content. Based on expert opinion of persons intimately familiar with the uranium pyrophoricity issue, there is no evidence that uranium metal that has had limited contact with water and been subsequently dried has an increased risk of pyrophoricity. The staff approves this material as approved content as long as it meets all other size and other restrictions on approved content in the CoC.

2.3 Radiolysis Evaluation

Uranium oxides

Previously UO_2, UO_3, and U_3O_8 had been approved as contents. Staff did not consider radiolysis to be an issue since the moisture content of the oxides was low (<3%) and they were packed in unsealed metallic convenience containers so the whole volume of the containment vessel was open to the generated gas.

Amendment 9 to CoC No. 9315 requests a reduction of the maximum allowable weight of oxide to 15.13 kgs for a maximum duration of one year. The applicant provided radiolysis calculations using reasonable or conservative assumptions regarding the “G” value for water in uranium oxides and available volumes for hydrogen containment. Under the assumption of a bounding “G” value, free access of the gas to the complete containment canister via an unsealed convenience container, 3% moisture in the oxide, and a 20% uncertainty margin, the applicant determined ~15 kg of the oxide could be transported, if the duration of containment was limited to 1.2 years. Since the “G’ value was not determined in an apparatus constructed from the same materials as the convenience container, and since the test configuration of oxide and container were not the same as the proposed situation, the staff does not endorse the calculational method used to arrive at the 15.13 kg of oxide. Since practical experience indicated the radiolysis is not an issue with the shipment of UO2 at the 3% moisture level, the staff feels that 15.13 kg of oxide can be safely shipped if the duration from sealing of the containment vessel to conclusion of shipping is less that 1 year.

Uranyl nitrate crystal

Currently, uranyl nitrate is not an allowed content because it has an adverse interaction with the approved metallic convenience containers. The applicant requested 4.75 and 11.9 kg of uranyl nitrate in the form of uranyl nitrate crystals, $UO_2(NO_3)_2 \cdot xH_2O$ where $x \leq 6$, to be added to the list of allowed contents to be transported in Teflon convenience containers. The exact amount was determined by the value of “x,” and a desired duration from the closure to opening of the containment canister. The applicant calculated the allowable weights of the content based on duration of either 1.2 or 0.6 years. Then, for conservatism, they reduced the durations to 1 year and 5 months respectively.

The amount of hydrogen generated was based on the “G” values determined for uranium oxides and neptunium oxides by Oak Ridge National Laboratory (ORNL). The water in the requested contents is bound to the crystal structure as opposed to free water in the radiolysis studies from which the "G" values were obtained. The bonds of the water to the crystal must be broken in addition to the radiolysis of the water to ions. In addition, the short range of the alpha radiolysis requires that it take place in the grain boundaries of the crystal, allowing more time for recombination than in the free water scenario. As a result, the application of the "G" values for determining the generation of hydrogen is considered conservative.

The extent of free flow between a Teflon container, which might gall and seal, and the containment canister could not be determined, and the only other mechanism for hydrogen to escape the convenience container would be by permeation of the hydrogen through the Teflon. The most conservative situation would be if the convenience container is sealed, thus the limiting volume for calculating the hydrogen buildup from permeation would be the volume of the containment vessel outside the convenience containers. Recognizing that there might be some leakage from the Teflon convenience container, a more realistic volume to use would be the volume equivalent to the average of the two pressure calculations. This is nominally a factor of three below the volumes given in SAR Table 3.6.7.1

The staff does not approve the use of Teflon convenience containers for the mass of uranyl nitrate and durations specified in Table 3.6.7.1 of the SAR. The staff finds that the approved content shall: 1) be limited to the masses of uranyl nitrate listed in SAR Table 3.6.7.1 and with durations where the material is enclosed in the convenience container combined not to exceed 4 months and 2 months respectively, or 2) limited to 1/3 of the masses in SAR Table 3.6.7.1 with durations where the material is enclosed in the convenience container for durations not to exceed 1 year and 5 months.

The staff evaluated the production of hydrogen gas and found it to be sufficiently low, under the restrictions in this analysis to be included in the CoC, to meet the requirements of 10 CFR 71.43(d)

2.4 Conclusions

Based on the application and the above discussion (with restrictions as stated), the staff has reasonable assurance that the package will meet the structural and materials requirements of 10 CFR Part 71.

3.0 THERMAL

The staff reviewed the application to revise the Model No. ES-3100 package thermal design and evaluation to assess whether the package temperatures will remain within their allowable values or criteria for NCT and HAC as required in 10 CFR Part 71. This application was also reviewed to determine whether the package fulfills the acceptance criteria listed in Section 3 (Thermal Review) of NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel."

3.1 Thermal Evaluation

This submittal (Revision 7 to the CoC for the Model No. ES-3100 transportation package) requested various changes including, but not limited to, revising the criticality safety calculations, adding a criticality safety index option, etc. Two of these changes potentially affect the thermal review:

- increasing the mass of off-gassing material in the containment vessel (use of Teflon bottles and polyethylene containers), which affects the operational pressures; and
- reducing the amount of maximum fissile material in the package from 36 kg to 35.2 kg including changes to the HEU isotopic composition which could have an effect on the decay heat of the package.

Regarding the effects of off-gassing inside the containment vessel, the applicant analyzed three new containment vessel arrangements (CVAs). These three new CVAs included shipments containing six nickel cans (each one 7.62 cm in diameter by 12.07 cm high), three polyethylene bottles (each one 12.54 cm in diameter by 22.1 cm high), and three Teflon bottles (each one 11.91 cm in diameter by 23.88 cm high).

The assumptions used in determining the maximum normal operating pressure (MNOP) include: (1) the temperature and pressure within the containment vessel is at 25° C and 14.7 psia, respectively, and the relative humidity is at 100% when initially closed; (2) the cans and bottles are sealed to minimize void volume inside the containment vessel; (3) can and bottle geometry does not change as pressure increases inside the containment vessel; and (4) all off-gassing material within the containment vessel (Teflon bottles, polyethylene bags or bottles, silicone pads) is limited to 1500 g.

The assumptions for determining the maximum hypothetical accident condition (HAC) pressure are the same as the MNOP, except the initial pressure and temperature within the containment vessel is the MNOP at ambient temperature. The applicant has identified that the MNOP has increased to 20 psia (up from 18 psia) and the maximum pressure under HAC has increased to 73.6 psia (up from 45 psia), both of which are still below the CVA design pressure of 116 psia. Even with a very conservative adjustment of 5% to the volume to account for hydrogen generation at the maximum permissible limit, the maximum pressure under HAC is still 50% below the design pressure. The applicant has reevaluated, per submittal dated February 24, 2009, the maximum pressures using the entire CVA volume minus the inner container volume and minus the content volume which produces a maximum pressure of 40 psia, which is lower than the original value of 45 psia previously mentioned. This approach removes assumption (2) from above and accounts for permeation of the hydrogen through the inner containers, as well as assumes the other gases leak out of the inner containers, which may not be entirely conservative. However, both approaches continue to demonstrate that the CVA pressures remain below the design pressure.

The maximum allowed 35.2 kg of HEU is limited to an isotropic composition and mass of:

Nuclide	Weight Percent	Mass (g)
U-232	0.000004	0.001408
U-233	0.600000	211.200000
U-234	2.000000	704.000000
U-235	54.895996 (was 57.095996)	19323.390592
U-236	40.000000	14080.000000
U-237	0.000000	0.000000
Transuranic	0.004000	1.408000
Np-237	2.500000 (was 0.300000)	880.000000
Total	100.000000	35200.000000

ORIGEN-S was used to determine the mass and decay heat of the parent and daughter products for 3.2 kg of HEU from 0 to 70 years. The results indicate that the mass remains constant (see Table 2 in Appendix 4.6.1 of the SAR) and the decay heat remains below 0.4 watts (see Table 3.2 of the SAR), which was the original maximum decay heat loading of the package. Since the decay heat loading has not changed, the original thermal analysis is still valid, as well as the calculated material temperatures.

3.2 Conclusion

Therefore, the staff concludes that this revision to CoC No. 9315 for the Model No. ES-3100 continues to meet the thermal requirements for NCT and HAC as required by 10 CFR Part 71.

4.0 CONTAINMENT

This section presents the results of the staff review of the containment design and analyses for the ES-3100 transport package for highly enriched uranium (HEU) to be used by BWXT Y-12 National Security Complex. The staff reviewed the application to revise the Model No. ES-3100 package to verify that the package containment design has been described and evaluated under NCT and HAC as required in 10 CFR Part 71. This application was also reviewed to determine whether the package fulfills the acceptance criteria listed in Section 4 (Containment Review) of NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel."

4.1 Description of the ES-3100 Containment System

The ES-3100 HEU packaging system has been developed by the Y-12 National Security Complex. ES-3100 packaging is used to transport bulk HEU in the form of oxide (UO_2, UO_3, or U_3O_8, U_3O_8-Al, or UO_2-Mg), uranium metal and alloy in the form of solid geometric shapes or broken pieces, uranyl nitrate (UNX) crystals and fuel elements from Training, Research, Isotopes, and General Atomics TRIGA reactors.

The ES-3100 is designed to transport eight different oxide categories referred to as Groups 1 through 8. Groups 1 through 7 are product oxides and Group 8 is skull oxide which is a mixture of graphite and U_3O_8. Uranium content of the oxides varies from 20% by weight to 84.5% by weight. The U-235 enrichment ranges from 19 wt% to 100 wt%.

Design analysis, full-scale testing, and similarity of the ES-3100 prototypes were used to demonstrate that the ES-3100 package with HEU is in compliance with the applicable containment requirements of 10 CFR Part 71. A bounding load case established for the ES-3100 package assumes that the maximum HEU content is 35.2 kg with a decay heat load of 0.4 W. Structural, thermal, and containment evaluations have demonstrated that the ES-3100 package with HEU content weight ranging from 2.77 kg to 35.2 kg meets the containment requirements specified in 10 CFR Part 71 for all conditions of transport.

Table 4.2 lists a summary of the containment boundary design and fabrication acceptance basis.

Table 4.2 Summary of the Containment Vessel Design and Fabrication Acceptance Criteria

Criteria	Value
Normal empty weight	15.10 Kg
Air fill medium temperature at loading	25°C
Air fill medium pressure at loading	101.35 kPa
Hydrostatic pressure test	1034 ± 34 kPa
Helium acceptance leakage rate	$L_T \leq 2.0 \times 10^{-7}$ cm^3/s
Air acceptance leakage rate	$L_T \leq 1 \times 10^{-7}$ ref-cm^3/s
Air Preshipment leakage rate	$L_T \leq 1 \times 10^{-4}$ atm-cm^3/s

A single containment vessel is used in the ES-3100 shipping package for transport of bulk HEU contents. The containment boundary of the ES-3100 package is a pressure vessel that is designed, fabricated, examined and tested in accordance with the *ASME Boiler and Pressure Vessel Code, Section III, Division I, Subsection NB (B&PVC, Sect. III, Div. I).* The containment body is constructed of 304L SS and is fabricated by one of the two methods. The first method uses a standard 40 SS pipe, a machined flat-head bottom forging and a machined top flange forging. Each of these pieces will be joined with circumferential welds. The second fabrication method for the ES-3100 containment vessel uses forging, flow forming, or metal spinning to create the complete body (flat bottom, cylindrical body, and flange) from a single forged billet or bar with final material properties in accordance with ASME SA-1 82 Type F304L. The top flange area using this fabrication technique is machined identically to that of the welded forging method.

The lid assembly consists of a sealing lid, closure nut, and external retaining ring. The containment vessel sealing lid is machined from Type 304 SS bar with final material properties in accordance with ASME SA-479. The containment vessel closure nut is machined from a Nitronic_'60 stainless-steel bar with material properties, in accordance with ASME SA-479. The lid assembly, with the O-rings in place, is joined together by torquing the closure nut and sealing lid assembly to 120 ± 5 ft-lb. The sealing lid portion of assembly is restrained from rotating during the torquing operation by two dowel pins installed in the body flange. This satisfies the requirements of 10 CFR 71.43(c) that, "*Each package must include a containment system securely closed by a positive fastening device that cannot be opened unintentionally or by a pressure that may arise within the package.*"

The effectiveness of the closure system is demonstrated by the NCT and HAC tests, which show that the complete containment system, including welds and O-ring seals, meet the leak tight criterion as defined in ANSI 14.5-1997.

The containment vessel O-rings are manufactured from an ethylene-propylene elastomeric. The O-rings are rated for continuous service as static face seal in the temperature range of -40°C to 150°C (-40°F to 320°F). The ES-3100 package O-rings are certified to ASTM D-2000. The licensee has demonstrated through leakage tests that the O-rings are leaktight over the temperature range of -40 to 205°C (-40 to 401°F) which is greater than the operating temperature range of -40 to 141.22°C (-40 to 286.2°F) of the ES-3100 containment vessel.

4.2 Containment Under Normal Conditions of Transport

In accordance with 10 CFR 71.51(a)(1), "*A Type B package, in addition to satisfying the requirements of 10 CFR 71.41 through 71.47, must be designed, constructed, and prepared for shipment so that under the tests specified in: (1) Section 71.71 ("Normal conditions of transport"), for normal conditions of transport (NCT) there would be no loss or disposal of radioactive contents-as demonstrated to a sensitivity of* 10^{-6} A_2 *per hour, no significant increase in external surface radiation levels, and no substantial reduction in the effectiveness of the packaging.:*" The licensee has used the guidelines of ANSI N14.5 to determine the leakage test which will demonstrate the ES-3100 transport packaging system meets the "no-loss" requirements of 10 CFR 71.51.

Even though the initial composition of the HEU contains several isotopes of uranium and transuranic contributors, the package contents will include, as a result of radioactive decay, daughter product isotopes at varying concentrations depending on the length of decay time. The licensee has calculated the A_2 value and the maximum content activity-to-A_2 ratio for the mixture of HEU with its isotopes and daughter isotopes at about 70 years of decay. These values are determined using a bounding case maximum of 35.2 kg of HEU.

The licensee's analysis assumes a worst case in which the total mass of uranium for each component is available for release as an aerosol. A bounding mass for the HEU content of 35.20 kg is used in the calculation for maximum allowable O-ring seal leakage rates for NCT and HAC. The worst-case maximum allowable leakage rates are used to calculate an equivalent leakage hole diameter using Appendix B of ANSI N14.5-1997 for each condition of transport. This leakage hole diameter is used to calculate a reference air and a helium leakage rate for leak testing. The O-ring seal leakage testing is expected to ensure that no leakage is greater than the leakage generated by the hole. The reference air leakage rate as defined in ANSI N14.5-1997 is the upstream leakage in air which is 3.2965×10^{-3} ref-cm^3/s. The allowable leakage rate at NCT using helium is calculated to be 3.5537×10^{-3} cm^3/s.

The containment criterion for the ES-3100 package is leaktight as stipulated in ANSI N14.5-1997 as having a leakage rate of ≤ 1.0×10^{-7} ref-cm^3/s during the prototype tests. This leaktight criterion satisfies the design verification requirement stipulated in ANSI N14.5-1997. The requirements of ANSI N14.5-1997 are used for all stages of containment verification for the ES-3100; namely, design, fabrication, maintenance, periodic, and shipment.

The containment vessel undergoes hydrostatic pressure testing to 150 psi after fabrication and before the final leakage test. Prior to the leakage test the containment vessel and O-ring cavity is thoroughly dried. The leak testing is performed with air or helium to either ≤ 1×10^{-7} ref-cm^3/s or 2×10^{-7} cm^3/s, respectively. This test ensures the integrity of the containment vessel in accordance with paragraph 6.3.2 of ANSI N14.5-1997.

The SAR demonstrates that the ES-3100 transport packaging satisfies the containment requirements of 10 CFR 71.51(a)(1) for normal conditions of transport.

4.3 Containment Under Hypothetical Accident Conditions

In accordance with 10 CFR 71.51(a)(2), "A *Type B package, in addition to satisfying the requirements of §§ 71.41 through 71.47, must be designed, constructed, and prepared for shipment so that under the tests specified in Section 71.73 ("Hypothetical accident conditions"), there would be no escape of krypton-85 exceeding 10* A_2 *in 1 week, no escape of other radioactive material exceeding a total amount* A_2 *in 1 week, and no external radiation dose rate exceeding 10 mSv/h (1 rem/h) at 1 m (40 in) from the external surface of the package."*
The licensee's analysis assumes a worst case scenario in which the total mass of uranium for each component is available for release as an aerosol. The leakage hole diameter found for the maximum allowable leakage rate for HAC is used to determine the reference air leakage rate. O-ring seal leakage testing is expected to assure that no leakage is greater than the leakage generated by the hole diameter. The HAC reference air leakage rate as defined in ANSI N14.5-1997 is found to be 5.7237 ref-cm^3/s and the allowable HAC leakage rate using Helium for leak testing is calculated as 5.4839 cm^3/s. These calculated values determine the acceptable test leakage rate for post-HAC leakage testing.

In accordance with 10 CFR 71.73(b), the initial pressure inside each test unit containment vessel should be the MNOP. Since the stresses at the MNOP was found to be insignificant compared to the allowable stresses, performing compliance testing with nominal pressure in the containment vessel has little or no significant effect on the results. The containment vessel did not exhibit any signs of damage and passed the post-test leak tests and the subsequent 10 CFR 71.73(c)(5) water immersion tests. The entire containment boundary was then helium leak checked and passed the leaktight criteria. No water was observed inside the test units' containment.

The 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 was maintained during the HAC testing.

The SAR demonstrates that the ES-3100 packaging satisfies the containment requirements of 10 CFR 71.51(a)(2) for hypothetical accident conditions.

4.4 Leakage Rate Tests

Shipping packages used to transport radioactive materials shall be fabricated, procured, and maintained in accordance with the applicable regulations, namely, 10 CFR Part 71. Compliance with Type B package containment boundary requirements shall be demonstrated by the design, fabrication, maintenance, periodic, and pre-shipment tests as listed in Table 1 of ANSI N14.5-1997.

The design, fabrication, maintenance, and periodic leakage rate limit is 1 x 10^{-7} ref-cm^3/s air. For the pre-shipment leakage rate test, the pass criterion is 1 x 10^{-4} ref-cm^3/s, which exceeds the requirement given in ANSI N14.5, paragraph 7.6.4. These criteria, if met, will demonstrate correct assembly of the containment vessel.

4.4.1 Design Leakage Test

The purpose of the design leakage rate test is to verify that a packaging design will contain radioactive material for both NCT and HAC as described in 10 CFR 71.71 and 10 CFR 71.73. The complete design verification testing of ES-3100 package for NCT was conducted at the maximum normal operating pressure (MNOP). Upon completion of design verification testing and sequential testing prescribed by 10 CFR 71.71, the containment vessel was removed from the drum assembly, and the cavity between the O-rings was leak tested. The test yielded a leak rate of 2.4773 x 10^{-5} ref-cm^3/s. Following this O-ring leak test, the entire containment boundary of the test vessel was helium leak tested that yielded a leakage rate of 2.0 x 10^{-7} cm^3/s after 20 minutes of testing.

The design verification tests were conducted following compliance tests in accordance with 10 CFR 71.71 and 71.73. The effectiveness of the closure system is demonstrated by the NCT and HAC tests, which show that the complete containment system, including welds and O-ring seals, meet the leaktight criterion as defined in ANSI N14.5-1997.

4.4.2 Fabrication Leakage Rate Test

The fabrication leak test is performed before the first use. The licensee assures that the fabrication leak test of the containment boundary is performed after the pressure test in accordance with ANSI N14.5-1997. The fabrication vacuum leak test demonstrates that the containment vessel is fabricated properly and that the containment boundary is leaktight.

4.4.3 Maintenance and Periodic Leak Test

Maintenance leak test is performed following repair or replacement of a containment system component or annually while the package is in use. Packages that are not in use and have not had a periodic leakage-rate test within the last 12 months are tested prior to use. The licensee assures that maintenance and periodic leak tests shall be performed using the same procedure and acceptance criteria as in the fabrication leakage rate test. With successful completion of the test, the entire containment boundary is considered leaktight.

4.4.4 Pre-shipment Leakage Rate Test

Pre-shipment leakage testing is performed prior to shipment of the containment vessel with its contents loaded and ready to be shipped. The licensee assures that the equipment used to perform the leak test is properly calibrated to ensure accuracy, and all leak testing is performed in accordance with a quality assurance program. The licensee further ensures that the test method used has a sensitivity of at least 1×10^{-4} ref-cm^3/s air.

4.5 Evaluation Findings

The staff has reviewed the evaluation of the containment system under normal conditions of transport and concludes that the package is designed, constructed, and prepared for shipment so that under the tests specified in 10 CFR 71.71 the package satisfies the containment requirements of 10 CFR 71.43(f) and 10 CFR 71.51(a)(1) for NCT with no dependence on filters or a mechanical cooling system.

The staff has reviewed the evaluation of the containment system under HAC and concludes that the package satisfies the containment requirements of 10 CFR 71.51(a)(2), with no dependence on filters or a mechanical cooling system.

In summary, the staff has reviewed the Containment Evaluation section of the SAR and concludes that the package has been described and evaluated to demonstrate that it satisfies the containment requirements of 10 CFR Part 71, and that the package meets the containment criteria of ANSI N14.5-1997.

5.0 SHIELDING

The staff reviewed the application to revise the Model No. ES-3100 package to verify that the shielding design has been described and evaluated under NCT and HAC, as required in 10 CFR Part 71. This application was also reviewed to determine whether the package fulfills the acceptance criteria listed in Section 5 (Shielding Review) of NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel."

5.1 Shielding Evaluation

The applicant revised the shielding evaluation in the SAR for the Model No. ES-3100 package to consider new contents, which increased the allowable contents of transuranic isotope ^{237}Np from 0.3% to 2.5%. Staff reviewed the transport package to verify that the revised package contents continue to meet the external radiation requirements of 10 CFR Part 71 under both NCT and HAC conditions.

The ES-3100 transport package is designed to transport bulk HEU in either metal, oxide, or nitrate crystal form. The shielding analysis considered a maximum enrichment of 92% ^{235}U, with maximum package loadings of either 36 kg of HEU metal or 24 kg of HEU oxide powder. The analysis of these models provides equivalent or bounding results that cover other proposed contents.

The package consists of stainless steel convenience cans loaded with HEU material, spacer assemblies, the containment vessel, and an insulation filled drum. The shielding model used for NCT is a simplified cylindrical model as denoted in Figure 5.1 of the SAR. Under HAC, the applicant assumed that the containment vessel and contents remain intact, but all exterior packaging materials are removed.

The expected radionuclide content for the package is specified in Table 5.3 in the SAR. The photon source data is given in Table 5.4, and the neutron source due to both spontaneous fission and alpha-n reactions is given in Table 5.5. These source spectra were determined using ORIGEN following a 10.5 year decay for the photon source and a 15 year decay for the neutron source. The decay allows for the build-in of daughter products which contribute significantly to the source term. Induced fission neutrons and secondary photons are included in the dose rate calculations. The uranium metal source term is assumed to be the same as that for the oxides, per unit HEU mass.

The applicant modeled a range of regular geometric shapes to maximize the resulting exterior dose. These shapes were then used to evaluate the dose under both NCT and HAC conditions. This analysis is required to evaluate the possible range of source geometry resulting from small irregularly shaped pieces of HEU metal subject only to a mass limit.

The applicant calculated external gamma and neutron dose rates at various radial and axial distances from the cask surface using the MORSE-CGA computer code. The resulting external dose rates are dominated by the gamma doses and are summarized in Table 5.1 and 5.2 of the SAR. Although there were slight increases in the overall doses due to the increased level of Neptunium, both the neutron and gamma radiation results in a NCT dose at the outer package surface of less than 200 mrem/h (2 mSv/h) and a one meter dose less than 10 mrem/h (0.1 mSv/h). This meets the 10 CFR 71.47(a) radiation dose limit for the external surface of a package being transported by nonexclusive use. Likewise, the HAC dose rate one meter from the external surface of the package increased marginally as well, but was still less than the limit of 1.0 rem/hr (10 mSv/h). This meets the requirements of 10 CFR 71.51(a)(2).

The staff performed a confirmatory analysis of the applicant's calculated external gamma dose rates using the MicroShield 5.05 point kernel gamma dose rate code. Using conservative material and geometry assumptions the staff calculated external gamma dose rates that confirmed those calculated by the applicant.

5.2 Conclusion

Based on review of the statements and representations in the application, the staff concludes that the shielding design has been adequately described and evaluated and that the package continues to meet the external radiation requirements of 10 CFR Part 71.

6.0 CRITICALITY

The staff reviewed the application to revise the Model No. ES-3100 package to verify that the criticality design has been described and evaluated under NCT and HAC, as required in 10 CFR Part 71. This application was also reviewed to determine whether the package fulfills the acceptance criteria listed in Section 6 (Criticality Review) of NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel."

6.1 Criticality Evaluation

6.1.1 Revised Fissile Material Contents

The applicant revised the criticality safety calculations and fissile loadings for most of the authorized contents of the ES-3100. The applicant had previously described the detailed characteristic data for the controlled mixture of the neutron absorber, Commercial product Cat. No 277-4, eliminating the need for bias correction due to material uncertainties for a previous revision. At that time, the revised criticality calculations in the application were not reviewed. These calculations have subsequently been reviewed and are the subject of this SER.

In most cases the amount of fissile material increased. There are a few cases where fissile material decreased. The fissile loadings are limited by either the criticality or structural analyses, or the hydrogen generation limit.

Additionally, the applicant added contents consisting of: 1) uranium metal cylinders with a diameter less than 4.25 inches, 2) skull oxides (U_3O_8 with residual graphite), and 3) uranyl nitrate hexahydrate crystals ($UO_2(NO_3)_2 \cdot 6H_2O$). There are no changes to the approved contents for TRIGA fuel.

The applicant also requested that the certificate be revised to allow the alloying elements aluminum and magnesium to be present for all metal shapes. In these cases, the fissile mass limit for uranium metal applies to the mass of the fissile uranium plus the mass of alloying elements.

6.2 Model Configuration

The applicant revised the content model to include large uranium metal cylinders, skull oxides, and uranyl nitrate crystals. The applicant also revised the models for several previously approved contents in order to support revised fissile material loadings. For all contents, the spacing and material provided by the metal convenience cans is conservatively neglected. The material of the Teflon or polyethylene bottles is considered with respect to its neutron moderating properties, but the spacing and confinement provided by these internal containers is not credited in the analysis. The package model (i.e., outer drum, kaolite, internal neutron absorber, containment vessel) remains largely the same as what was assumed for the previously approved contents, with respect to materials of construction and package configuration under NCT and HAC.

6.2.1 Solid Uranium Metal or Alloy of Specified Geometric Shapes

For the high enriched uranium metal cylinders and square bars, the applicant modeled the cylinders and bars stacked directly on top of each other for configurations with no spacers, or separated by the 277-4 spacers for configurations requiring spacers. The applicant showed that this is the most conservative configuration. The applicant also evaluated variations in spacing of the cylinders and bars, but found close spacing within the containment vessel to be the most reactive condition.

For the varying enrichment uranium metal slugs, the applicant evaluated various arrangements of slugs within the containment vessel, as described in Appendix 6.9.1 of the SAR. These arrangements included variations in slug pitch and packing density, as well as several non-uniform arrangements of the slugs. The staff confirmed that the applicant performed sensitivity studies to determine the most reactive configuration of slugs.

The applicant also evaluated uranium alloys of aluminum, molybdenum, and zirconium for all uranium metal configurations. The applicant demonstrated that these alloys are bounded by the uranium metal analyses, as long as the alloying element is treated as fissile material when determining the mass of the contents to be shipped.

6.2.2 Broken Uranium Metal or Alloy of Unspecified Shapes

For the varying enrichment broken uranium metal content, the applicant evaluated the use of several different content configurations, as discussed in Appendix 6.9.1 of the SAR. The most reactive configuration was found to be the uranium metal content homogeneously mixed with water in the containment vessel.

6.2.3 Uranium Oxide

For the uranium oxide powder content, the powder is assumed to collect at the bottom of the containment vessel to a height determined by the quantity and bulk density of the powder. Water is then assumed to saturate the powder to an increasing degree until the powder is 100% saturated (i.e., water fills the volume defined by the maximum theoretical density of the UO_2 minus the bulk density of the powder). Bulk densities of UO_2 powder typically vary from around 2.0 to a maximum of 6.54 g/cm^3. The applicant varied the oxide density for each mass considered in order to find the most reactive configuration. This same modeling technique is used for UO_3, U_3O_8, and skull oxide contents. Note that UO_3 and U_3O_8 were found to be less reactive than UO_2, and that the UO_2 content limit is conservatively applied to these other two oxide forms.

For the skull oxide contents, the applicant evaluated U_3O_8 content containing up to 921 grams of graphite. These contents may also contain a limited amount of “unidentified material,” which, for the purposes of evaluation and actual transportation, is considered to be fissile material.

The applicant’s uranium oxide criticality analysis supported a maximum ^{235}U content of 9.682 kilograms, within either UO_2, UO_3, or U_3O_8. The maximum overall oxide limit is 15.13 kilograms, based on the hydrogen generation analysis in Section 3 of the SAR.

6.2.4 Uranyl Nitrate Crystals

For the uranyl nitrate crystal content, water was assumed to mix with the crystals to form a solution of uranyl nitrate which is allowed to fill the entire volume of the containment vessel. The applicant evaluated the uranyl nitrate crystals in the package containment vessel with 500 grams polyethylene homogeneously mixed with the contents, as well as with water densities varying from dry to fully moderated. The applicant also considered configurations where reduced loadings of uranyl nitrate go into solution, with the remainder of the contents accumulated in the bottom of the containment vessel.

6.2.5 Hydrogenous Packing Material

For all of the content models, the applicant considered the addition of 500 grams of polyethylene packaging material, which may be used to package the allowable contents. For the uranium oxide, skull oxide, and uranyl nitrate hexahydrate content models, 500 grams of polyethylene is conservatively modeled homogeneously mixed with the fissile material.

For the solid geometric shapes, the applicant's calculations do not account for the presence of hydrogenous packing material, however, the applicant evaluated varying thicknesses of polyethylene external to the bulk metal, and found that this increased the spacing and reduced neutron communication between the various metal pieces in the containment vessel.

Staff calculations show an increase in k_{eff} when polyethylene is homogeneously mixed with the water or when all three fissile masses are surrounded by the polyethylene. However the increase is not substantial and is bounded by the conservative assumptions of the analysis. The staff finds the applicant's modeling acceptable as is but acknowledges that future changes to the contents (fissile material or hydrogenous packing material) may warrant further scrutiny of the modeling assumptions.

For the broken metal contents, the applicant performed sensitivity studies where the homogenized contents were confined to smaller regions of the vessel comparable to the size of the convenience cans. In these sensitivity studies, the applicant added 500 grams of polyethylene to the homogenized contents. The applicant showed in Tables 6.9.11b and 6.9.11c of the SAR that for each mass and enrichment loading, with and without spacers for NCT and HAC, the analysis where the mass was uniformly distributed over the entire volume of the containment vessel was more conservative.

The staff accepts the homogenous model as the most conservative representation of the broken metal. However, since hydrogenous material was not added to this model, the staff does not approve hydrogenous packing material to be shipped with the broken metal at this time.

6.3 Computer Codes and Cross-Section Libraries

The applicant used the CSAS25 sequence of the SCALE 4.4a code system with the KENO V.a three-dimensional Monte Carlo criticality transport program and the 238-group ENDF/B-V cross section library for all k_{eff} calculations. The SCALE code system is a standard in the nuclear industry for performing Monte Carlo criticality safety and radiation shielding calculations

The staff used either the MCNP three dimensional Monte Carlo neutral particle transport code with continuous energy ENDF/B-VI cross sections, or the CSAS26 sequence of the SCALE code system with the KENO VI three-dimensional Monte Carlo criticality transport program and the 238-group ENDF/B-VI cross section library.

6.3.1 Confirmatory Calculations

The staff performed independent calculations verifying that the ES-3100 meets the subcritical limit with the modified fissile masses and new Cat. 277-4 specifications. The staff modeled the contents similar to the description for each limiting case in Table 6.9.1.1. All empty spaces within packaging were filled with water. All cases were modeled either as infinite arrays or as 5N arrays under NCT, which were generally more limiting than the 2N arrays under HAC. Spaces between the packages within the array were modeled as void. Finite arrays were surrounded by 30 centimeters of water. The packaging was modeled using Figures 6.6 through 6.10, corresponding to the array packaging assumptions.

The staff made several assumptions in the confirmatory model in order to simplify the analysis. The staff neglected the stainless steel surrounding the kaolite drum and absorber, and the Silicon pads on the bottom of the package. The staff used an “equivalent” amount of Silicon on the top of the containment vessel upper flange rather than model the top and sides explicitly. The staff assumed that the Kaolite that makes up the plug and body welding is the same density and that the kaolite was flooded as are all empty spaces in the packaging. The material properties came from the array calculations models for HAC in Table 6.4 of the SAR.

The staff used the same specifications for Kaolite that the applicant used in their SCALE models. However, the staff performed additional calculations varying the density and water content of the Kaolite and found that the specifications used by the applicant are conservative.

6.3.1.2 Solid Uranium Metal or Alloy of Specified Geometric Shapes

The staff modeled the specified geometric shapes the same as the applicant specified in Table 6.9.1.1. The results of the staff’s calculations are within 2% of the applicant’s.

The staff also performed calculations to confirm that replacing a varying amount of fissile material with an alloying element did not result in a more reactive condition. In all cases, k_{eff} of the system dropped as more alloying element was added, confirming the applicant’s conclusion that uranium alloys of aluminum, molybdenum, and zirconium are bounded by the uranium metal configurations.

6.3.1.3 Broken Uranium Metal or Alloy of Unspecified Shapes

The staff modeled the broken metal the same as the applicant specified in Table 6.9.1.1. The results of the staff's calculations are within 2% of the applicant's.

6.3.1.4 Uranium Oxides

The staff modeled the uranium oxide content in the containment vessel using assumptions similar to the applicant. The UO_2 content was modeled with varying bulk density between 2.0 and 6.54 grams/cm^3, and with varying water density allowed to mix homogeneously with the UO_2. The staff confirmed the applicant's findings that the k_{eff} raised with decreasing powder density, as this allowed more water to mix with the fissile material to provide a greater degree of moderation.

6.3.1.5 Uranyl Nitrate Crystals

The staff modeled the uranyl nitrate hexahydrate content in the containment vessel using assumptions similar to the applicant. The $UO_2(NO_3)_2 \cdot 6H_2O$ content was modeled dry at its theoretical density of 2.79 grams/cm^3, and varying water density was allowed to mix homogeneously with the uranyl nitrate content in solution. The results of the staff's calculations confirm the applicant's findings that the package with be safely subcritical for the mass loadings of uranyl nitrate crystals listed in Table 1.3a of the SAR for a criticality safety index (CSI) of either 0.0 or 0.4.

6.4 Benchmark Evaluations

Benchmark evaluations were performed for uranium systems as described in Appendix 6.9.8 of the SAR. This section provides a generic benchmark analysis of the CSAS25 sequence of SCALE 4.4a for a variety of uranium systems. A total of 639 uranium critical experiments were modeled in order to determine a bounding upper subcritical limit for all uranium systems modeled using SCALE 4.4a. The resulting upper subcritical limit determined by the applicant is 0.925 for all analyses performed for the ES-3100. Although the benchmarking analysis uses an upper subcritical limit based on a wide variety of systems in reference to the specific systems modeled for the ES-3100 criticality analysis, it is the judgment of the staff that this limit is bounding and conservative. Therefore, it is acceptable for the analyses presented in the application.

6.5 Conclusion

Based on review of the statements and representations in the application, the staff concludes that the nuclear criticality safety design has been adequately described and evaluated and that the package meets the subcriticality requirements of 10 CFR Part 71.

7.0 PACKAGE OPERATIONS

The staff reviewed Chapter 7 of the SAR in the application to revise the Model No. ES-3100 package to verify that it continues to meet the requirements of 10 CFR Part 71 and is adequate to assure the package will be operated in a manner consistent with its evaluation for approval.

To support this revision request, Section 7.1.3.3 of the SAR was revised to include the requirements prior to shipping. Section 7.2.1 was revised to include requirements upon receipt of the package. Staff specified a condition for a shorter shipping time than that proposed by the applicant (Condition No. 5.(b)(3)) for uranyl nitrate crystals and specifies this for the incorporation of Chapter 7 into the CoC.

Based on the statements and representations in the application, the staff concludes that the package operations meet the requirements of 10 CFR Part 71 and that they are adequate to assure the package will be operated in a manner consistent with its evaluation for approval. Further, the CoC is conditioned to specify that the package must be prepared for shipment and operated in accordance with the Operating Procedures in Chapter 7 (with the exception of the shipping times for UNX crystals in Section 7.1.3.3, No. 2) of the application.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

The staff reviewed Chapter 8 of the application to verify that the revised acceptance tests for the packaging meet the requirements of 10 CFR Part 71. There were no changes made to this chapter in this revision.

CONDITIONS

The CoC has been revised as follows:

Condition No. 5(a)(3)(i):

> One drawing was revised to change the data plate.

Condition No. 5(b):

> The contents description was changed to add nylon bags and Teflon bottles. The concentration of neptunium was also changed.

Condition No. 5(b)(1):

> Condition was updated to provide clarification on the spacers.

Condition No. 5(b)(1)(i):

> Condition was changed to update the metal and alloy geometric shapes and their loading limits.

Condition No. 5(b)(1)(ii):

Condition was changed to update the broken metal loading limits.

Condition No. 5(b)(2):

Condition was changed to update the oxide requirements.

Condition No. 5(b)(3):

Condition was changed to add the uranyl nitrate crystal requirements.

Condition No. 10:

Condition was changed to approve the use of nylon bags.

Condition No. 11:

Condition was changed to clarify any unknown constituents.

Condition No. 13(a):

Condition was changed to clarify requirements for uranyl nitrate crystals.

Condition No. 20:

Condition allows the use of Revision 8 of this certificate for one year.

CONCLUSION

Based on the statements and representations in the application, as supplemented, and the conditions listed above, the staff concludes that the Model No. ES-3100 package design has been adequately described and evaluated and that these changes do not affect the ability of the package to meet the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9315, Revision No. 9,
on May 8, 2009.