U.S. DEPARTMENT *of* ENERGY

Office of Environmental Management

DOE Packaging Certification Program

SAFETY EVALUATION REPORT
Letter Amendment of Certificate of Compliance No. 9979 for the Model 9979 Package

Docket No. 26-35-9979

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This Safety Evaluation Report (SER) documents the U.S. Department of Energy (DOE) Packaging Certification Program (PCP) independent review of an addendum to the Safety Analysis Report for Packaging (SARP) for the 9979 Package, prepared by the Savannah River National Laboratory (SRNL) for the Savannah River Operations Office (SR) for amendment of DOE Certificate of Compliance (CoC) Number 9979, Revision 20 to authorize use of the package for limited shipments of fuel compacts.

Evaluation

By email [1] dated April 30, 2026, SR submitted a request to authorize use of the Model 9979 for limited shipments of high-assay low-enriched uranium (HALEU) tri-structural isotropic (TRISO) fuel compacts from the National Criticality Experiments Research Center in Nevada to the Valar Atomics Ward 250 reactor site in Utah. The application in support of this request is an addendum [2] to the SARP [3] that demonstrates the package is subcritical under normal conditions of transport (NCT) and hypothetical accident conditions (HAC). The addendum was revised May 18, 2026 [4-5] to correct decay heat and A_2 mixture errors noted by DOE PCP staff.

This new package content configuration consists of 170 unirradiated TRISO fuel compacts housed in a single graphite block (Valar Atomics Drawing - WARD250 FUEL BLOCK). The compacts are secured in the block with threaded graphite plugs. The block is placed in unsealed polyethylene bagging prior to loading in the 30-gallon drum, then loaded in the drum with custom fit polyethylene foam for dunnage. The U-235 mass in the block is 234.94 grams at less than 20% enrichment. This content configuration is bounded by the SARP and CoC, except for nuclear criticality safety (NCS), since this configuration has not been analyzed.

The applicant performed a new nuclear criticality safety evaluation (NCSE) [6] of this content configuration of an infinite array of packages under NCT and a 5x5x4 array (100 packages) under HAC that demonstrate subcriticality of the most reactive conditions and determine the criticality safety index (CSI). The NCSE results are summarized in Chapter 6 of the addendum to the SARP.

DOE PCP staff's review of the review and confirmatory analysis of the addendum and NCSE are presented in the following sections of this SER. This content configuration will be referred to in this SER as the "TRISO fuel block."

1. Packaging and Contents

There were no changes requested by the applicant or required to the packaging design for use to ship the TRISO fuel block. When used for transport of unirradiated TRISO fuel compacts, the graphite block is required for convenience handling and retention of the fuel compacts.

The TRISO fuel block contents, content configuration, and packing (loading) instructions for the 30-gallon drum are described in Section 1.2.2, *Contents*, Table 1, *Valar Atomics Fuel Element Specifications*, and Table 2 *Representative Uranium Composition of TRISO Particles* of the addendum. Table 1 includes the graphite block dimensions from Valar Atomics Drawing No. V-002782, *WARD250 FUEL BLOCK*, and shown in Figure 1, *Valar Atomics Fuel Element* of the addendum. TRISO fuel compacts are secured in the graphite block fuel channels with threaded graphite plugs.

DOE PCP staff notes that the bagging for the TRISO fuel block contents must not be sealed. This

condition will be included in the letter amendment.

Based on review of the statements and representations in the SARP and this addendum, DOE PCP staff concludes that the package design has been described in sufficient detail to provide an adequate basis for its evaluation relative to the regulatory requirements in 10 CFR 71.

2. Structural Evaluation

There were no changes requested by the applicant or required to the packaging design for use to ship the TRISO fuel block.

The TRISO fuel block mass (per Table 1 of the addendum) is approximately 49.052 kg (108.14 lb.), and with bagging and dunnage is bounded by the package content mass limit of 90 kg, per the SARP and CoC.

The radioactive (unirradiated TRISO compacts) and non-radioactive (graphite) materials of the TRISO fuel block have been previously evaluated per § 71.43(c) for other approved contents in the package, per CoC Tables 1 and 2.

Although the applicant does not credit the graphite block as an important-to-safety component of the package design; nevertheless, the applicant included the mechanical properties of the graphite (Grade E10) in Table 3: *Valar Atomics Fuel Element Graphite Properties*, of the addendum, and how graphite is used as for dunnage and convenience handling in other package applications. The end use of the TRISO fuel block (post transportation) is as fuel element in the Valar Ward 250 Microreactor.

ET-10 graphite is engineered to withstand high-pressure and high-temperature environments without deforming. Its tensile and impact strength are relatively low; consequently, it may crack or chip under sharp impact or under tension. During package transport, the TRISO fuel block will be bagged and enveloped in custom fit polyethylene foam dunnage. During transport, the TRISO fuel block is principally loaded in compression and isolated by the dunnage from impact with sharp objects or tension that could cause it to crack or chip; therefore, DOE PCP staff has reasonable assurance that the graphite block is expected to retain its structural integrity and the configuration as evaluated in the NCSE for NCT and HAC.

Based on review of the statements and representations in the SARP and this addendum, DOE PCP staff concludes that the existing package structural design is sufficient to meet the requirements of 10 CFR Part 71 for shipment of these contents.

3. Thermal Evaluation

There were no changes requested by the applicant or required to the packaging design for use to ship the TRISO fuel block.

The calculated estimate of the decay heat generated from the TRISO fuel block is 5.33E-04 watt, per Table 4, *Valar Atomics Fuel Element Estimated Decay Heat and A2 Fraction*, of the addendum, which is significant less than package limit of 3.5 watts per the SARP and CoC.

Due to the low decay heat of the contents, the graphite block preventing direct contact of the TRISO fuel compacts with hydrogenous material (unsealed plastic bagging and dunnage), and the large void

volume in the drum, the applicant expects hydrogen gas generation in the 30-gallon drum to be negligible, by comparison with similar contents authorized in the CoC. DOE PCP staff concurs with the applicant's reasoned argument.

The TRISO fuel block configuration meets the "Non-combustible" payload category of CoC Table 1. In addition, polyethylene, which is the material used for bagging and dunnage with this configuration, is evaluated and authorized for use in the 30-gallon drum per SARP Section 3.4.2.5, *Contents Pyrolysis/Ignition Potential during HAC Fire*. The autoignition temperature of polyethylene is approximately 660°F, which is greater than the maximum calculated content temperature (400°F) in the 30-gallon drum under thermal HAC, per SARP Table 3.15 – *Calculated Temperatures at End of 30-Minute HAC Fire*. Gases generated during HAC are vented from the pressure relief device in the 30-gallon drum lid. The TRISO fuel block configuration is bounded by the existing thermal evaluation.

Based on review of the statements and representations in the SARP and this addendum, DOE PCP staff concludes that the existing package thermal design is sufficient to meet the requirements of 10 CFR Part 71 for shipment of these contents.

4. Containment Evaluation

There were no changes requested by the applicant or required to the packaging design for use to ship the TRISO fuel block.

The package is limited to a Type A quantity of radioactive material. The TRISO fuel is solid normal form radioactive material. The radioactive contents are estimated and calculated in Table 4, *Valar Atomics Fuel Element Estimated Decay Heat and A_2 Fraction* of the addendum and show the calculated A_2 value is 0.184 and thus does not exceed an A_2 for the mixture.

Based on review of the statements and representations in the SARP and this addendum, DOE PCP staff concludes that the existing package containment design is sufficient to meet the requirements of 10 CFR Part 71 for shipment of these contents.

5. Shielding Evaluation

There were no changes requested by the applicant or required to the packaging design for use to ship the TRISO fuel block.

The package TRISO fuel block is a Type A quantity or of radioactive material. For Type A fissile packages, shielding reviews are not necessary because, by the nature of the contents, radiation source terms and radiation levels for these packages are negligible (Ref. NUREG-2216, Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material, Section 5.4).

The packaging design does not include engineered features specifically intended to provide radiation shielding of the TRISO fuel block.

Compliance with § 71.47 is confirmed by measurement for each package prior to shipment.

6. Criticality Evaluation

There were no changes requested by the applicant or required to the packaging design for use to ship

the TRISO fuel block. This configuration is not bounded by a comparable configuration in the SARP or its supplements authorized in Revision 20 of the CoC; consequently, the applicant performed NCSE calculations of the TRISO fuel block configuration to determine the number of packages that could be shipped on a single consignment in compliance with §§ 71.55 and 71.59. The NCSE results are presented in Chapter 6 of the addendum.

The purpose of the DOE PCP staff criticality review is to confirm that the package together with its contents meets the requirements in 10 CFR Part 71 for NCS. Staff reviewed Chapter 6 of the addendum and its supporting NCSE (N-NCS-G-00206, Rev. 0) for the proposed shipment of the TRISO fuel block configuration described in Section 1.2.2.1, *Contents of the Packaging,* of the addendum. Staff reviewed the applicant's NCSE methodology, assumptions, single package (SP) evaluation, modeling approaches for NCT and HAC arrays, and performed independent confirmatory calculations using MCNP 6.3 to verify subcriticality of the package, under the most reactive conditions.

The applicant summarized the results of the NCSE in Section 6.1.2 *Summary Table of Criticality Evaluation*, and Table 5 *Summary of Criticality Safety Evaluation*, of the addendum. The k_{safe} value, of 0.920, is reported in Table 5. The criticality safety index (CSI), 1.0, is addressed in Section 6.1.3 *Criticality Safety Index,* and Table 6 *Criticality Safety Index Calculations*, of the addendum.

6.1. Package Description

The Model 9979 packaging consists of a 30-gallon drum nested within a 55-gallon drum overpack as described in the CoC and SARP. There were no changes to the packaging design for the TRISO fuel block configuration.

The hexagonal graphite block is defined in Valar Atomics Drawing No. V-002782 and is approximately 13.13-in wide (across parallel faces) and 11.81-in tall. The block includes 34 fuel channels, evenly spaced in a hexagonal array, for loading five TRISO compacts in each channel. The compacts are secured in its fuel channel by a threaded graphite plug. The block also includes three threaded holes 120-degress apart for lifting attachments, coolant channels and a control rod channel which are not used in the transportation configuration of the block.

A TRISO compact is a cylinder approximately 0.5 in. in diameter and 2 in. tall and is made by compressing (compacting) thousands of TRISO particles into a solid shape. A TRISO particle (spherical) is approximately 1 mm is diameter and comprised of a uranium oxycarbide (UCO) fuel kernel surrounded by layers of porous carbon, pyrolytic carbon, and silicon carbide. Uranium in TRISO particles is enriched to a maximum of 19.9 wt.% U-235 and the remaining uranium consists mostly of U-238 and trace quantities of U-233, U-234, and U-236, as shown in Table 2 *Representative Uranium Composition of TRISO Particles*, of the addendum.

The fissile mass of the contents is described in Section 6.2 of the addendum and consists of 170 TRISO compacts, totaling 234.94 grams of U-235 (1.33 g U-235/compact), at 20.0 wt.% maximum enrichment, in a graphite block. The NSCE assumed a bounding case where the compacts totaled 239.19 grams of U-235 (1.407 g U-235/compact), at 21 wt.% enrichment.

6.2 Summary of NCSE and Staff's Confirmatory Evaluation

The applicant evaluated package subcriticality of the TRISO fuel block in NCT and HAC array

configurations using the SCALE 6.1/KENO VI code system with the 238-group ENDF/B-VII Release 0 cross section library. The limiting condition was identified as the HAC configuration consisting of a 5×5×4 array of damaged packages. The maximum k_{eff} +2*sigma observed for this finite array is 0.403, which occurs for the flooded case with void/air between packages and the fuel block centered in the drum. The acceptance criterion applied in the applicant's analysis is k_{safe} = 0.920.

Single Package
The applicant used analysis-by-comparison to demonstrate subcriticality of a single package (SP) configuration to demonstrate compliance with § 71.55(b), based on the maximum mass of U-235 (239.19 grams) of a TRISO fuel block is significantly below the single-parameter subcritical metal mass limit for of U-235 of 700 grams for uniform aqueous systems per ANSI/ANS-8.1-2014, *Nuclear Criticality Safety in Operations*. DOE PCP staff agrees this comparison is a valid and conservative single-parameter screening basis, given the low fissile mass, the solid TRISO/graphite fuel form, and the substantial subcritical margin shown in the array calculations.

NCT Array
The applicant's NCT array analysis considered 12 cases (total) of an infinite triangular-pitched close packed array of undamaged packages, with 30-cm of water (reflection on all sides) or air between the packages. The TRISO fuel block was positioned at the side-bottom or mid-center of the 30-gallon drum, and the 30-gallon drum was dry (unmoderated), or flooded with water (max. moderation), or filled with polyethylene material (moderation/reflection). The results are summarized in Table 7 *Infinite NCT Array Analysis Results* of the addendum. All case results were below k_{safe}. The most reactive configuration was Case 11, where k_{eff} +2*sigma of 0.314 occurs when the 30-gallon drum is filled with polyethylene and the fuel block is centered in the drum. The applicant demonstrates compliance with the requirements of §§ 71.55(d) and 71.59(a)(1).

HAC Array
The applicant's HAC model simulates a damaged package condition by omitting the 55-gallon drum overpack and the insulation between the 55-gallon and 30-gallon drums, which allows closer spacing than undamaged packages. The applicant's HAC array analysis in the NCSE considered 6 cases of an infinite triangular-pitched close packed array of damaged packages reflected by 30 cm of water, with the space between the drums occupied by water or air, the fuel block centered in the package, and the package interior dry, flooded with water, or filled with polyethylene material. The most reactive case (NCSE Table 6-3, *HAC Infinite Array Results,* Case 2), occurs when the package interior is dry and space between packages is occupied by air. Case 2 had a k_{eff} +2*sigma of 0.991 which exceeds k_{safe}. Consequently, the applicant reduced the size of the array to 5x5x4 (100 packages) and ran 12 cases (NCSE Table 6-4, *HAC 5x5x4 Array Results*) of the smaller array with the fuel block centered or at the side of the package.

The NCSE results are summarized in Table 8, *5×5×4 Array HAC Analysis Results*, of the addendum. All case results were below k_{safe}. The most reactive configuration was Case 7, where k_{eff} +2*sigma of 0.403 occurs when the package is filled with flooded with water, the space between packages is occupied by air, and the fuel block is centered in the package. The applicant demonstrates compliance with the requirements of §§ 71.55(e) and 71.59(a)(2).

The NCSE notes that alternate configurations of the fuel block in the package, such as multiple fuel blocks facing each other between adjacent packages, were considered but were not explicitly modeled

based on the low calculated $k_{eff}+2\sigma$ values (range 0.378 to 0.403) vs. k_{safe} of 0.920 for the analyzed cases and engineering judgment that additional cases would not significantly close that margin. DOE PCP staff notes that additional cases of the alternate configuration of the fuel block may have provided a more solid basis for the applicant's conclusion, but agrees with the applicant's argument that additional cases are not necessary given the large margin of $k_{eff}+2\sigma$ vs. k_{safe} in the NCSE for the HAC 5x5x4 array (100 packages/fuel elements), as confirmed by staff's independent calculations, and the fact only 24 packages (24 fuel elements) would be authorized for shipment under this letter amendment to the DOE CoC.

Confirmatory Analysis
DOE PCP staff performed independent confirmatory calculations using MCNP 6.3 with ENDF/B-VIII.0 cross sections for selected NCT and HAC cases. The selected cases included the reported limiting NCT infinite-array case, the reported limiting finite HAC case, and two additional representative finite HAC shifted cases. Representative results from the applicant analysis and the staff's confirmatory calculations are provided in Table 6-1.

Representative results from the applicant's SARP Addendum & NCSE and DOE PCP staff's confirmatory calculations are provided in Table 6-1 below. Staff's confirmatory calculations are generally consistent with the applicant's results and did not identify discrepancies that would challenge the reported reactivity trends or subcriticality conclusions. Staff's calculated values remain well below $k_{safe} = 0.920$ for all evaluated cases. Staff's result for the reported limiting HAC case, HAC_Tmix_fld_v3_f_vbtw, is $k_{eff} = 0.4020$, agrees with the applicant's reported $k_{eff} = 0.4020$.

Table 6-1 SARP Addendum and Staff's Confirmatory Criticality Safety Calculations of Limiting Conditions

SARP Addendum (NCSE) Table	Array Desc.	Case #	Case	SARP $k_{eff} \pm \sigma$	Staff $k_{eff} \pm \sigma$
7 (Table 6-2)	NCT (infinite)	11	NCT_Tmix_poly_v3_vbtw	0.3124 ± 0.0004	0.3073 ± 0.0002
8 (Table 6-4)	HAC (5x5x4)	6	HAC_Tmix_fld_v3_f_fbtw_shft	0.3859 ± 0.0003	0.3867 ± 0.0003
		7	HAC_Tmix_fld_v3_f_vbtw	0.4020 ± 0.0003	0.4020 ± 0.0003
		10	HAC_Tmix_poly_v3_f_fbtw_shft	0.3834 ± 0.0003	0.3892 ± 0.0002

6.3 Conclusion
Based on review of the statements and representations in the SARP, this addendum, and its supporting NCSE, DOE PCP staff has reasonable assurance that the administrative controls of the package contents have been adequately described and evaluated and that the package continues to meet the NCS requirements of 10 CFR Part 71 for shipment of TRISO fuel blocks.

7. Package Operations
There were no changes requested by the applicant or required to the packaging design for use to ship the TRISO fuel block. The TRISO fuel block contents are prepared and loaded in accordance with Section 1.2.2.3, *Packing Configuration*, of the addendum and restrictions per Section 1.2.2.2, *Payload Limits and Restrictions*, of the SARP.
The TRISO fuel block configuration, with polyethylene bagging and foam dunnage, is considered a "noncombustible" payload; therefore, usage of insulation bag is optional. The hydrogen generation rate in the 30-gallon drum with these contents is low due to the facts that there is no direct contact

between radioactive materials and hydrogenous materials (e.g., plastics, water, etc.), and decay heat rate of this shipping configuration is low (5.3E-04 watts), so hydrogen generation and accumulation in the 30-gallon drum is negligible. The bagging surrounding the TRISO fuel block will not be sealed, so there is no layer of confinement to accumulate hydrogen in this packing configuration. There are no packaging engineering or administrative controls related to flammable gas generation – the Compact Augmented Permeation System (CAPS) device configuration is not required or void volume limits in for 30-gallon drum. Therefore, DOE PCP staff confirmed by document review that the package operation requirements in SARP Chapter 7 are adequate for use of the package to ship the TRISO fuel block.

Based on review of the statements and representations in the SARP and this addendum, DOE PCP staff concludes that the operating procedures meet the requirements of 10 CFR Part 71 and that these procedures are adequate to assure the package will be operated in a manner consistent with its evaluation for approval.

8. Acceptance Tests and Maintenance Program

There were no changes requested by the applicant or required to the packaging design for use to ship the TRISO fuel block.

The end use of the TRISO fuel block (post transportation) is as a fuel element in the Valar Ward 250 Microreactor. The graphite block is fabricated in accordance with Valar Atomics Drawing No. V-002782, *WARD250 FUEL BLOCK*. However, it is used for convenience handling of the TRISO fuel compacts and is not credited as an import-to-safety packaging component. Therefore, there are no acceptance tests and maintenance program requirements for use of the graphite block in the package.

Based on review of the statements and representations in the SARP and this addendum, DOE PCP staff concludes that the acceptance tests for the packaging meet the requirements of 10 CFR Part 71 and that the maintenance program is adequate to assure packaging performance during its service life.

9. Quality Assurance

There were no changes requested by the applicant or required to the packaging design for use to ship the TRISO fuel block.

The graphite block is not an important-to-safety packaging component; consequently, there are no changes to SARP Chapter 9, *QUALITY ASSURANCE*, for the TRISO fuel block configuration.

Based on review of the statements and representations in the SARP and this addendum, DOE PCP staff concludes that the applicant's QA program has been adequately described and meets the QA requirements of 10 CFR 71.

Conclusion

Based on the statements and representations in the SARP and this addendum, and the conditions listed in this SER, DOE PCP staff independently confirmed by document review that the package content change has been adequately described and evaluated. Therefore, the staff has reasonable assurance that the Model 9979 package design continues to meet the requirements of 10 CFR Part 71, recommends approval and issuance of a letter amendment to the CoC by the DOE Headquarters Certifying Official (HCO).

Conditions of Approval

The following conditions are required in a letter of authorization issued by the DOE HCO to authorize use of the package for limited shipments of TRISO fuel compacts.

DOE CoC No. 9979, Revision 20 is amended to authorize use of the Model 9979 package for limited shipments subject to the conditions below:

1. Authorized package contents are defined in Section 1.2.2 of Safety Analysis Report for Packaging Model 9979 Type A Fissile Shipping Package Addendum 1 Valar Atomics Fuel Elements, S-SARP-G-00006 Addendum 1, S-SARA-G-00023 Revision 1.
2. Each package is limited to 170 TRISO fuel compacts secured in the WARD250 Fuel Block (Drawing V-002782).
3. The fissile mass limit per package is 234.94 grams of U-235. (Note - NCSE evaluated 239.19g).
4. The maximum U-235 enrichment is less than 20 weight percent. (Note - NCSE evaluated at 21 wt.%).
5. Content restrictions per Section 1.2.2.2 of the *Safety Analysis Report for Packaging Model 9979 Type AF Shipping Package*, S-SARP-G-00006, Revision 7.
6. Contents are prepared for loading in the package in accordance with Section 1.2.2.3 of S-SARA-G-00023 Revision 1. Bagging must be unsealed.
7. The criticality safety index (CSI) is 1.0.
8. All other conditions of DOE CoC No. 9979 shall remain the same.
9. This authorization expires on June 30, 2027, or at completion of shipments, whichever occurs first.

References

[1] *DOE-SR concurrence for DOE PCP review of S-SARP-G-00006 Rev. 8*, Email, L. Sobus to C. Cable, dated April 30, 2026.
[2] *Safety Analysis Report for Packagings Model 9979 Type AF Shipping Package - Addendum 1 Valar Atomics Fuel Elements*, S-SARA-G-00023 Revision 0, April 2026
[3] *Safety Analysis Report for Packagings Model 9979 Type AF Shipping Package*, S-SARP-G-00006, Revision 7, December 2020.
[4] *FW: Request for DOE PCP Review of S-SARA-G-00023, Rev. 1*, Email, L. Sobus to L. Gelder, dated May 19, 2026.
[5] *Safety Analysis Report for Packagings Model 9979 Type AF Shipping Package - Addendum 1 Valar Atomics Fuel Elements*, S-SARA-G-00023 Revision 1, May 2026
[6] *Nuclear Criticality Safety Evaluation: Tri-Structural Isotropic (TRISO) Fuel Compacts in the 9979 Type AF Shipping Package*, N-NCS-G-00206, Revision 0, April 29, 2026.