



## U.S. DEPARTMENT *of* ENERGY

# Office of Environmental Management

## *DOE Packaging Certification Program*

### **Safety Evaluation Report for Amendment and Renewal of Certificate of Compliance No. 9228 for the Model GE-2000, Serial Number 2003**

**Docket No. 25-25-9228**

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This Safety Evaluation Report (SER) documents the U.S. Department of Energy (DOE) Packaging Certification Program (PCP) independent technical review and confirmatory analysis of the application submitted for the Oak Ridge National Laboratory (ORNL) Site Office (OSO) for amendment and renewal of DOE Certificate of Compliance (CoC) Number 9228 for the Model GE-2000, Serial Number 2003 package design. This package is needed to support the mission of the ORNL.

## SUMMARY

By letter <sup>[1]</sup> dated May 28, 2025, the OSO requested amendment and renewal of DOE CoC No. 9228 Revision 2. The request was supported by an application which consisted of *Safety Analysis Report for Packaging (SARP) for the GE-2000 HFIR Irradiated Fuel Element Transport Package, Rev. 2.* <sup>[2]</sup>

The applicant modified the design of the package payload, that is, the fuel elements, but did not change the design of the packaging. The fuel element dimensional tolerances were revised to provide flexibility for reasonable variation in the design parameters. These changes did not increase the maximum weight of the fuel elements or the maximum uranium weight per fuel element. The changes to the SARP are described in a summary detail and evaluated for compliance with 10 CFR Part 71 in two enclosures <sup>[3-4]</sup> submitted with the SARP to justify the changes. The SARP was revised to implement the fuel element design changes as follows:

- Chapter 1, Figures 1-6 and 1-7 updated with the nominal fuel dimensions,
- Chapter 1, Appendix 1.4.1, fuel element drawings updated from Rev 1 to Rev 2:
  - *HFIR Inner Fuel Element GE2000 Shipping Cask Certification Drawing*, M-11524-OH-101, Rev. 2.
  - *HFIR Outer Fuel Element GE2000 Shipping Cask Certification Drawing*, M-11524-OH-102, Rev. 2

The applicant also updated SARP Chapter 9 (Quality Assurance) for consistency with the latest ORNL Quality Assurance Program approved by the DOE Certifying Official (CO) per DOE Order 460.1D.

Based on the statements and representations in SARP Revision 2, and DOE PCP staff's independent confirmatory review and evaluation described in this SER, the staff finds this amendment and renewal request acceptable and will provide reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met subject to the Conditions in the CoC.

## EVALUATION

The following sections in this SER document DOE PCP staff's chapter-by-chapter independent review and evaluation of the design and performance of the package for safety and regulatory compliance in general information and drawings, structural, thermal, containment, shielding, criticality safety, operating procedures, acceptance tests and maintenance program, and quality assurance (QA) as demonstrated in the SARP Rev. 2, to confirm it contains a sufficient safety basis for approval of the package design to the requirements of 10 CFR Part 71.

### 1. General Information

The objective of this review is to verify that the package design has been described in sufficient detail to provide an adequate basis for its evaluation under 10 CFR Part 71. The design must be shown on engineering drawings that can be referenced in the certificate of compliance.

There were no changes to the packaging design or content limits for the package payload of High Flux Isotope Reactor (HFIR) fuel elements. The HFIR fuel element drawings in SARP Appendix 1.4.1 were revised to update the dimensional tolerances of the fuel element to provide flexibility for reasonable variation in the design parameters.

SARP Figures 1-6 and 1-7 were updated with the nominal fuel dimensions. SARP Appendix 1.4.1, fuel element drawings were updated from Rev 1 to Rev 2:

- *HFIR Inner Fuel Element GE2000 Shipping Cask Certification Drawing*, M-11524-OH-101, Rev. 2.
- *HFIR Outer Fuel Element GE2000 Shipping Cask Certification Drawing*, M-11524-OH-102, Rev. 2

The applicant made marginal (small) changes to some of the HFIR fuel element dimensions and increased the default tolerance for all nominal dimensions from  $\pm 0.005$  to  $\pm 0.025$  in. per Note 3 on both drawings (M-11524-OH-101 and M-11524-OH-102). There were no changes to the lengths of the "active fuel element" except to change the length from a "reference" to nominal dimension. There were no changes to the overall nominal diameter for either fuel element.

The marginal changes to the inner fuel element (IFE) include revising the overall length from a range 30.275 to 30.225 in. to nominally 30.250 in., increasing the bore diameter from 5.059 to 5.064 in., and revising axial dimensions at the bottom of the IFE.

The marginal changes to the outer fuel element (OFE) include revising the overall length of the from a range 31.140 to 31.110 in. to nominally 31.125 in. and revising axial dimensions at the top and bottom of the OFE.

These dimension and tolerance changes did not change the maximum weight per fuel element or maximum mass of U-235 per element. (Ref. General Notes on M-11524-OH-101 and M-11524-OH-102).

The applicant included a table with all the dimensional changes to both HFIR fuel elements in

the summary <sup>[3]</sup> provided with the SARP.

Based on review of the statements and representations in the SARP and HFIR drawings, 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**

The objective of this review is to verify that the structural performance of the package design has been adequately evaluated for the tests specified under normal conditions of transport (NCT) and hypothetical accident conditions (HAC), and that the package has adequate structural integrity to meet the requirements of 10 CFR Part 71.

There were no changes to the structural design of the packaging due to the minor changes to fuel element designs. These dimension and tolerance changes to the fuel elements did not change the maximum weight per fuel. There were no changes in SARP Chapter 2 or its appendices to implement the fuel element changes.

DOE PCP staff evaluated the impact of the fuel element design changes and concurred that since the IFE and OFE do not directly contact the Cask cavity, the changes in fuel dimension tolerances have no effect on the structural performance or evaluation of the package.

The applicant estimated, using finite element analysis, the minimum separation of the active fuel regions from the 30-ft. free drop of the package in a top-down drop orientation was 1.177 in. as shown in SARP Appendix 2.13.13, *Structural Evaluation of the HFIR Fuel Basket and Liner*, Figure 2.133, *Worst Credible Accident Condition, 30 Foot Head On Drop*. This separation distance is compared with SARP Table 6.6, *Criticality Analysis Results as a Function of Fuel Element Separation/Overlap* to demonstrate the fuel elements remain subcritical. SARP Table 6.6 shows that  $k_{\text{eff}}$  increases as the separation of the active fuel regions decreases (and overlaps). The applicant demonstrates, by comparison, that the tolerance change of the fuel element dimensions could impact the minimum separation distance by less than 0.1 in., and therefore remain subcritical per Table 6.6. DOE PCP concurs with the applicant's analysis by comparison.

Based on review of the statements and representations in the SARP, DOE PCP staff concludes that the structural design has been adequately described and evaluated and that the package has adequate structural integrity to meet the requirements of 10 CFR Part 71.

## **3. Thermal Evaluation**

The objective of this review is to verify that the thermal performance of the package design has been adequately evaluated for the thermal tests specified under NCT and HAC, and that the package design meets the thermal performance requirements of 10 CFR Part 71.

There were no changes to the thermal design of the packaging due to the minor changes to fuel element designs. These dimension and tolerance changes to the fuel elements did not change the maximum weight per fuel element or maximum mass of U-235 per element. There were no changes in SARP Chapter 3 or its appendices to implement the fuel element changes

The IFE and OFE are both modeled using an axisymmetric finite element model with a course mesh as shown SARP Figure 3.1, *Thermal Finite Element Model*. The total heat load of the Cask is unchanged at 600 watts, and 166 watts from the IFE and 434 watts from the OFE per SARP Section 3.4.1.2. Heat flux of the IFE/OFE are calculated at nominal dimensions as shown in SARP Section 3.4.1.3. The radial gaps between the IFE/OFE and the basket wall are not critical since only conduction between these surfaces are considered due to limited clearance at nominal dimensions. Consequently, the nominal dimension and tolerance changes to the fuel elements are too small to have a discernable effect on the thermal performance of the package under normal and accident conditions. DOE PCP staff concurs that these marginal changes are bounded by the existing SARP thermal evaluation of package performance.

Based on review of the statements and representations in the SARP, DOE PCP staff concludes that the thermal design has been adequately described and evaluated, and that the thermal performance of the package meets the thermal requirements of 10 CFR Part 71.

#### **4. Containment Evaluation**

The objective of this review is to verify that the package design satisfies the containment requirements of 10 CFR Part 71 under NCT and HAC.

The package containment boundary is leaktight per ANSI N14.5-2014, per SARP Section 4.3.3.

There were no changes to the containment design of the packaging due to the minor changes to fuel element designs, which did not increase the package content activity. There were no changes in SARP Chapter 4 or its appendices to implement the fuel element design changes. DOE PCP staff concurs that these marginal fuel element design changes are bounded by the existing package containment boundary performance.

Based on review of the statements and representations in the SARP, DOE PCP staff concludes that the containment design has been adequately described and evaluated and that the package design meets the containment requirements of 10 CFR Part 71.

#### **5. Shielding Evaluation**

The objective of this review is to verify that the package design meets the external radiation requirements of 10 CFR Part 71 under NCT and HAC.

There were no changes to the shielding design of the packaging due to the minor changes to fuel element designs, which did not increase the package content activity. These dimension and tolerance changes to the fuel elements did not change the maximum weight per fuel element or maximum mass of U-235 per element. There were no changes in SARP Chapter 5 or its appendices to implement the fuel element design changes. DOE PCP staff concurs that these marginal fuel element design changes are bounded by the existing package shielding design performance.

There were no changes to source-term, burn-up, and cooling time of the fuel elements. The

physical location of the IFE and OFE within the Cask is constrained by the HFIR basket which remains unchanged. While the nominal and dimensional tolerance changes to the fuel elements may contribute to marginal limited displacements within the constraints of the HFIR basket, the applicant's simplified geometry shielding model analysis cases described in SARP Section 5.3.1. address such movement so that the applicant's shielding analysis results remain bounding. DOE PCP staff concurs that these marginal fuel element design changes are bounded by the existing package radiation shielding evaluation.

Based on review of the statements and representations in the SARP and DOE PCP staff concludes that the shielding design has been adequately described and evaluated and that the package meets the external radiation requirements of 10 CFR Part 71.

## 6. Criticality Evaluation

The objective of this review is to verify that the package design meets the nuclear criticality safety (NCS) requirements of 10 CFR Part 71 under NCT and HAC.

There were no changes to the nuclear criticality safety design of the packaging due to the minor changes to fuel element designs. These dimension and tolerance changes to the fuel elements did not change the maximum weight per fuel element or maximum mass of U-235 per element. There were no changes in SARP Chapter 6 or its appendix to implement the fuel element design changes. DOE PCP staff concurs that these marginal fuel element design changes are bounded by the existing package nuclear criticality safety design performance.

There were no changes to the fuel enrichment or the total amount or configuration of fissionable material within the fuel plates. The physical location of the IFE and OFE within the Cask is constrained by the HFIR basket which remains unchanged. Based on the structural evaluation in this SER Section 2.0, the minimum separation of the active fuel regions from the 30-ft. free drop of the package in a top-down drop orientation was 1.177 in. as shown in SARP Appendix 2.13.13, *Structural Evaluation of the HFIR Fuel Basket and Liner*, Figure 2.133, *Worst Credible Accident Condition, 30 Foot Head On Drop*. This separation distance is compared with SARP Table 6.6, *Criticality Analysis Results as a Function of Fuel Element Separation/Overlap* to demonstrate the fuel elements remain subcritical. SARP Table 6.6 shows that  $k_{\text{eff}}$  increases as the separation of the active fuel regions decreases (and overlaps). The applicant demonstrates, by comparison, that the tolerance change of the fuel element dimensions could impact the minimum separation distance by less than 0.1 in. That is, could change the minimum separation from 1.177 in. to 1.077 in. SARP Table 6.6 shows the reactivity for nominal separation of 1.5 in. is  $k_{\text{eff}} + 2\sigma = 0.9278$  and for 1.0 in. is 0.9332. Both results are well below the maximum allowable design limit  $k_{\text{eff}} + 2\sigma$  of 0.95 per SARP 6.4.3, *Criticality Results*. Therefore, the maximum possible IFE/OFE dimensional fuel changes do not affect the bounding criticality results. DOE PCP concurs with the applicant's analysis by comparison.

Staff concurs that marginal dimensional tolerance changes to the fuel elements will not appreciably impact the amount of moderator in the fuel plate cooling channels. In addition, staff concurs that the impact on reactivity due to the marginal reductions in the fuel element bore diameter is negligible and within the statistical uncertainty of applicant's criticality analyses. The

sub-critical cases described in SARP Table 6.6 bound any reactivity increase that would be expected from the IFE/OFE dimensional tolerance changes.

Based on review of the statements and representations in the SARP, DOE PCP 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. Operating Procedures**

The objective of this review is to verify that the operating controls and procedures meet the requirements of 10 CFR Part 71 and that the operating procedures are adequate to ensure the package will be operated in a manner consistent with its evaluation for approval.

There were no changes to the package/packaging operating procedures due to the minor changes to fuel element designs. These dimension and tolerance changes to the fuel elements did not change the maximum weight per fuel element or maximum mass of U-235 per element. There were no changes in SARP Chapter 7 or its appendices to implement the fuel element design changes, since the fuel elements are referenced by their description (outer and inner fuel element) and not by drawing/revision number. DOE PCP staff concurs that these marginal fuel element design changes have no impact on operating procedures for the package.

Based on review of the statements and representations in the SARP, 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**

The objective of this review is to verify 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.

There were no changes to the packaging acceptance tests and maintenance program due to the minor changes to fuel element designs. There were no changes in SARP Chapter 8 to implement the fuel element design changes, since the fuel elements are contents, not packaging components. DOE PCP staff concurs that these marginal fuel element design changes have no impact on acceptance tests and maintenance program for the packaging.

Based on review of the statements and representations in the SARP, 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**

The objective of this review is to verify that the applicant's Quality Assurance (QA) program description is approved by the DOE Certifying Official and the application demonstrates that the package-specific QA requirements comply with the requirements of 10 CFR Part 71.

The applicant's 10 CFR 71 Subpart H Quality Assurance Program (QAP), *Packaging Quality Assurance Program Description Applicable to Type B or Fissile Packaging (PQPD)*, dated March 26, 2024, and submitted April 4, 2024, is approved by DOE ([https://rampac.energy.gov/docs/default-source/qa/approval\\_0012\\_r4.pdf](https://rampac.energy.gov/docs/default-source/qa/approval_0012_r4.pdf)).

There were no changes to the packaging QAP due to the minor changes to fuel element designs. There were no changes in SARP Chapter 9 or its appendix to implement the fuel element design changes, since the fuel elements are contents, not packaging components. DOE PCP staff concurs that these marginal fuel element design changes have no impact on QAP for the packaging.

The applicant updated SARP Chapter 9 for consistency with the PQPD. DOE PCP staff reviewed and confirmed the updates were implemented in the SARP.

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

### **CONDITIONS OF APPROVAL**

The following changes to CoC Rev 2 are required to implement changes evaluated in this SER.

- Note – style changes throughout (“in.”, “lb.”, “n,nnn”, etc.)
- 3(2) *Title and Identification of report or application*: Revise to “... ORNL/RRD/INT-161, Rev.2, May 2025, ...” (SARP Rev 2)
- 3(3) *Date*: Revise to “May 2025” (SARP Rev 2)
- 5(b)(1) *Type and Form of Material*:
  - (i) Revise to “... *HFIR Fuel Inner Element*, M-11524-OH-101, Rev. 2, and *HFIR Fuel Outer Element*, M-11524-OH-102, Rev. 2 ...” (update fuel element drawing revisions).
- 5(d) *Conditions*:
  - (4) Revise to “...consign the package for domestic transport.” (added domestic for consistency with latest DOE certificates).
  - (5) Revise to “... certified package for domestic transport ...” (added domestic for consistency with latest DOE certificates),
  - (6) Revise to “Revision 2 of this certificate may be used until August 31, 2026.” (grace period).
- 5(e) *Supplements*:
  - Revise to “none”

### **CONCLUSION**

Based on the statements and representations contained in the SARP, and the conditions listed above, DOE PCP staff concludes that the package design has been adequately described and evaluated, and the Model 9516 package continues to meet the requirements of 10 CFR Part 71.

## REFERENCES

- [1] *Request for Renewal of Department of Energy (DOE) Certificate of Compliance Number 9228, GE-2000 High Flux Isotope Reactor (HFIR) Irradiated Fuel Element Transport Package*, Letter, W. Wheeler to J. Shenk, May 28, 2025.
- [2] *Safety Analysis Report for Packaging: GE-2000 HFIR Irradiated Fuel Element Transport Package*, ORNL/RRD/INT-161, Rev. 2, May 2025.
- [3] *Summary of Changes ORNL/RRD/INT-161, Rev. 2 Safety Analysis Report for Packaging: GE-2000 HFIR Irradiated Fuel Element Transport Package*, Enclosure 1, May 28, 2025.
- [4] *Evaluation of Changes ORNL/RRD/INT-161, Rev. 2 Safety Analysis Report for Packaging: GE-2000 HFIR Irradiated Fuel Element Transport Package*, Enclosure 2, May 28, 2025.