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**DOE Packaging Certification Program**

**Safety Evaluation Report for  
Certificate of Compliance No. 9228 Amendment for the  
Model 2000 Package**

**Docket No. 22-34-9228**

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This Safety Evaluation Report (SER) documents the U.S. Department of Energy (DOE) Packaging Certification Program (PCP) independent technical review of the application submitted by the package Certificate Holder, the Oak Ridge National Laboratory Site Office (OR), to authorize an optional change to the fuel element design for shipment in the Model GE-2000.

## Summary

By application <sup>[1]</sup> submitted April 13, 2022, the certificate holder, OR requested an amendment of DOE CoC 9228 for the Model GE-2000 package design to authorize an optional change to the Irradiated High Flux Isotope Reactor (HFIR) fuel assembly fuel element design.

The applicant requested the option to ship HFIR fuel that is modified, prior to irradiation, by installation of aluminum fuel element combs (i.e., spacers). Fuel element comb segments are spot welded onto the top of the fuel plates to form two concentric rings to provide rigidity, reduce end vibration, and minimize the probability of plate deflection due to thermal hydraulic forces on the fuel plates during reactor operation.

The fuel element combs have no impact on packaging and transportation safety. The applicant revised their Safety Analysis Report for Packaging (SARP) and HFIR fuel element drawings referenced (M-11524-OH-101 and M-11524-OH-102) in Section 5.(b)(1)(i) of the CoC to implement this optional change to HFIR fuel elements.

Based on the statements and representations in the SARP, DOE PCP staff independently confirmed that the package design has been adequately described and evaluated for this optional change to HFIR inner and outer fuel elements. Therefore, staff has reasonable assurance that the regulatory requirements of Part 71 have been met and recommends amendment of the CoC by the DOE Headquarters Certifying Official (HCO).

## **Evaluation**

This SER documents the independent technical review by DOE PCP staff of the application, *Safety Analysis Report for Packaging: GE-2000 HFIR Irradiated Fuel Element Transport Package*, ORNL/RRD/INT-161, Rev. 1, Page Changes, February 2022, to the requirements of 10 CFR Part 71.

### **1.0 General Information**

#### **1.1 Introduction**

The fuel element combs ((hereinafter referred to in the SER as “combs” unless otherwise stated)) were initially used in the early operating history of the HFIR to stabilize the fuel plates but discontinued after a short period following successful testing of a fuel element in the reactor for a full cycle without the combs. At that time, it was surmised by ORNL Engineering that the risk of damaging a fuel element during installation of the combs by full circumferential welds around the fuel element was greater than plate deflections during reactor operation.

However, following the *Performance Degradation of the Outer Fuel Element* occurrence in 2018 (<https://orpspublic.doe.gov/SC-OSO--ORNL-X10HFIR-2018-0005>), deformation was observed only on the outer fuel element plates. The fuel design was subsequently revised to allow the option of installing fuel element combs on the outer fuel element, by spot welding, prior to loading fuel in the reactor. The combs successfully operated on multiple outer fuel elements since approval of the design change modification.

The page changes to the SARP and its fuel element drawings are necessary to authorize the use of the package for shipment of irradiated HFIR fuel with combs installed.

There were no changes to the packaging design or its package analysis in SARP Chapters 2 through 9 to the requirements on 10 CFR Part 71.

#### **1.2 Package Description**

The Model GE-2000 is a Type B(U)F-96 package certified by DOE for shipment of irradiated HFIR fuel assemblies.

##### **1.2.1 Packaging**

There were no design changes to the packaging components described in the SARP and authorized in the CoC.

##### **1.2.2 Contents**

There were no changes to the type of form or material, maximum quantity of radioactive material, or the HFIR fuel assembly limits evaluated in the SARP and authorized in the CoC.

The applicant revised SARP Section 1.2.2, *Contents*, to include the option to use fuel element combs (e.g., in the shape of a hair comb) on the inner and out fuel elements, and to describe their material (6061 aluminum), location and method of installation (spot welded onto the top of the fuel plates in two concentric circles), and reactor safety function (provide rigidity, reduce end vibration, and to minimize the probability of plate deflection due to thermal hydraulic forces on the fuel plates during reactor operation).

The applicant revised the following drawings in SARP Appendix 1.4.1 to add the combs:

Drawing M-11524-OH-101-D, Rev. 1, *HFIR Fuel Inner Element*  
Drawing M-11524-OH-102-D, Rev. 1, *HFIR Fuel Outer Element*

Note - the “-D” suffix in the above drawing numbers is the drawing size and is not essential to include in the reference to the drawing number.

### **1.3 Evaluation Findings**

Based on review of the statements and representations in the SARP, DOE PCP staff concludes that the package in support of the CoC amendment request has been described in sufficient detail to provide an adequate basis for staff to evaluate it for compliance with 10 CFR Part 71.

### **2.0 Structural Evaluation**

The objective of this structural evaluation is to determine that the information presented in the SARP, including the description of the packaging, design and fabrication criteria, structural material properties, and structural performance of the package design for the tests under NCT and HAC, is complete and meets the requirements of 10 CFR Part 71.

The combs are part of the non-radioactive material (aluminum) of the contents. The combs are not important to package safety.

The combs are approximately 0.063 inch thick (1/16-inch), 0.25 inch tall with a 0.2-inch tooth length and span the circumference of each fuel element in two concentric circles as shown in the revised fuel element drawings. The combs add approximately 2-3 ounces to weight of each fuel element. The fuel elements with combs may not exceed its maximum weight: 110 lb. and 215 lb. for the inner and outer elements respectively; consequently, the additional marginal weight contribution from the combs is insignificant and does not affect the applicant’s structural analysis of the package.

The combs are fabricated from 6061 aluminum alloy which is the same aluminum alloy as the HFIR fuel element inner and outer shell and cladding; consequently, the combs meet the requirements of §71.43(d) with respect to material of construction. The weld filler material used for spot welding the combs is not specified in the SARP or drawings, so DOE PCP staff requested and reviewed the applicant’s welding procedure<sup>[2]</sup> to

confirm that the filler material (ER4943, 5.5% silicon aluminum) is likewise materially compatible with the package contents and packaging components.

Staff did not evaluate the likelihood of fuel cladding failure under NCT or HAC due to attachment of the combs since the fuel cladding is not a credited important-to-safety packaging component (SARP Section 2.11).

## **2.1 Evaluation Findings**

Based on review of the statements and representations in the SARP, DOE PCP staff has reasonable assurance that the package structural design continues to meet the requirements of 10 CFR Part 71

## **3.0 Thermal Evaluation**

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

Since the combs are extremely light (2-3 ounces), thin (0.063 inch thick) and are located at the top of the fuel element outside the heat producing fuel regions of the fuel plates, they cannot significantly affect the temperature distribution in the fuel elements or the thermal design of the package under NCT or HAC. The combs are fabricated from the same material as the HFIR Fuel Elements which is evaluated in SARP Section 3.4.5 and Table 3.5, *Thermal Properties of HFIR Fuel Element Aluminum (Type 6061) Material*.

## **3.1 Evaluation Findings**

Based on review of the statements and representations in the SARP, DOE PCP staff has reasonable assurance that the thermal design of the package continues to meet the requirements of 10 CFR Part 71.

## **4.0 Containment Evaluation**

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

No portion of the HFIR Fuel Assembly (e.g., cladding) is a credited safety feature for meeting the "leaktight" criteria of the package containment design in SARP Chapter 4.

## **4.1 Evaluation Findings**

Based on review of the statements and representations in the SARP, DOE PCP staff has reasonable assurance that the containment design of the package continues to meet the requirements of 10 CFR Part 71.

## **5.0 Shielding Evaluation**

The purpose of the shielding review is to confirm that the package (the packaging together with its contents) meet the external radiation requirements in 10 CFR Part 71.

The combs do not provide any significant gamma or neutron attenuation and their irradiation does not provide a source term that could affect the shielding evaluation of the package. DOE PCP staff finds that there are no failure mechanisms related to the combs that could affect the package shielding design and bounding shielding calculations in the SARP.

### **5.1 Evaluation Findings**

Based on review of the statements and representations in the SARP, DOE PCP staff has reasonable assurance that the package shielding design continues to meet the requirements of 10 CFR Part 71.

## **6.0 Criticality Evaluation**

The purpose of the criticality review is to confirm that the package together with its contents meet the requirements in 10 CFR Part 71 for nuclear criticality safety (NCS).

The NCS design of the package is provided by the structural integrity of the HFIR Fuel Basket and Liner by maintaining axial separation between the inner and outer HFIR fuel elements. The structural analysis of the package and fuel basket (SARP Chapter 2) shows that geometry of the package contents, without the fuel element combs, remain unchanged throughout HAC (and therefore NCT). The combs are not credited as a NCS control component for the package.

### **6.1 Evaluation Findings**

Based on review of the statements and representations in the SARP, DOE PCP staff has reasonable assurance that the package criticality design continues to meet the requirements of 10 CFR Part 71.

## **7.0 Operating Procedures**

The SARP provides a description of package operations, including package loading and unloading operations, and the preparation of an empty package for shipment. Loading and unloading procedures show a general approach to perform operational activities because site-specific conditions may require the use of different equipment and loading or unloading steps.

The combs would be added to fuel elements prior to irradiation, before the fuel is prepared for loading in the package. The irradiated fuel elements approved for shipment (SARP Section 7.1.2.1, *Loading HFIR Fuel*) is determined in advance of package operations. The absence or presence of the combs on the fuel plates is not germane to package operations.

## **7.1 Evaluation Findings**

Based on review of the statements and representations in the SARP, DOE PCP staff concludes that the combination of the engineered safety features of the package and the operating procedures provide adequate measures and reasonable assurance for safe operation of the package in accordance with 10 CFR Part 71.

## **8.0 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.

The combs are optional parts of the authorized contents and their acceptance occurs prior to transport from the facility. The absence or presence of the combs is not germane to acceptance tests and maintenance program for the packaging.

## **8.1 Evaluation Findings**

Based on the 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.

## **9.0 Quality Assurance**

The objective of this review is to verify that the SARP demonstrates that the applicant's Quality Assurance (QA) program description and package specific QA requirements comply with the requirements of 10 CFR Part 71, Subpart H, Quality Assurance.

The applicant's 10 CFR 71 Subpart H Quality Assurance Program (QAP) is approved by DOE ([https://rampac.energy.gov/docs/default-source/qa/approval\\_0012\\_r3.pdf](https://rampac.energy.gov/docs/default-source/qa/approval_0012_r3.pdf)).

The fuel element combs are defined on the revised fuel element drawings (M-11524-OH-101 and M-11524-OH-102, Rev. 1) and are installed per the drawing notes at the discretion of the HFIR System Engineer. The combs are not classified as a packaging components and are not assigned a QA category. They do not support the safety function of any of the packaging components and their presence or absence does not adversely affect the performance of any packaging components.

## **9.1 Evaluation Findings**

Based on review of the statements and representations in the SARP, DOE PCP staff has reasonable assurance that the package-specific requirements are consistent with their DOE approved QAP, meet the requirements of 10 CFR 71 Subpart H, and are therefore adequate to assure the package will be operated in a manner consistent with its evaluation for approval.

## Conditions of Approval

The following conditions are required to amend the CoC based on this SER.

- 5.(b)(1)(i): Change the revisions from 0 to 1 and omit the drawing size from the drawing number for drawings: *HFIR Fuel Inner Element*, M-11524-OH-101 and *HFIR Fuel Outer Element*, M-11524-OH-102.
- 5.(d)(6): Change to “Revision 1 of this certificate may be used until August 31, 2023.”
- 5.(e): Add Supplement (1) – “*Safety Analysis Report for Packaging: GE-2000 HFIR Irradiated Fuel Element Transport Package*, ORNL/RRD/INT-161, Rev. 1, Page Changes, February, 2022.”

## 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 GE-2000 package continues to meet the requirements of 10 CFR Part 71, and recommends amendment of the CoC by the DOE Headquarters Certifying Official (HCO).

## References

- [1] *Safety Analysis Report for Packaging: GE-2000 HFIR Irradiated Fuel Element Transport Package*, ORNL/RRD/INT-161, Rev. 1, Page Changes, February, 2022.
- [2] *Welding Procedure Specification (WPS) AWS D1.2 HFIR Fuel Comb Fillet Tack Welds*, GT23.23-6 (ST), Revision 3, March 25, 2021.