Safety Evaluation Report for the Hanford Unirradiated Fuel Package Safety Analysis Report for Packaging HNF-28554, Revision 2, August 2008

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CONTENTS

TABLES

FIGURES

ACRONYMS

ANSI	American National Standards Institute
ANL	Argonne National Laboratory
ASME	American Society for Mechanical Engineers
ASTM	American Society for Testing and Materials
BPVC	(ASME) Boiler and Pressure Vessel Code
CGOC	Center of Gravity Over Corner
CoC	Certificate of Compliance
CSI	Criticality Safety Index
DOE	U.S. Department of Energy
FH	Fluor Hanford
HAC	Hypothetical Accident Conditions
MCNP	Monte Carlo Nuclear Particle
MNOP	Maximum Normal Operating Pressure
NCT	Normal Conditions of Transport
NRC	Nuclear Regulatory Commission
QA	Quality Assurance
PRG	Packaging Review Guide
SAR	Safety Analysis Report
SARP	Safety Analysis Report for Packaging
SHCS	Socket-Head Cap Screw
SI	System of Units
SRNL	Savannah River National Laboratory
SS	Stainless Steel
SSCs	Structures, Systems, Components
TI	Transport index
TID	Tamper-indicating device
USL	Upper Safety Limit.

OVERVIEW

This Safety Evaluation Report (SER) documents the DOE Packaging Certification Program (PCP) Staff review of the *Safety Analysis Report for Packaging (SARP) for the Hanford Unirradiated Fuel Package (HUFP)*, Revision 2 dated August 2008.[1] Quality Assurance meets the requirements of 10 CFR 71, Subpart H.

Background

The HUFP is designed in accordance with the requirements of 10 CFR 71[2] and 49 CFR 173[3] to provide a safe means of transporting one core component container (CCC) housing MOX driver fuel assemblies (DFAs) or multiple IDENT-69G containers housing loose fuel pins. The packaging design can carry up to seven DFAs (within a CCC) or six IDENT-69G containers, all loaded in excess of 20 Ci of plutonium. The HUFP transports in excess of 30,000 Ci of radioactive material, resulting in a Category I designation.

The HUFP utilizes the same containment body and impact limiters as those of the Mixed-oxide (MOX) Fresh Fuel Package (MFFP).[4] However, the HUFP design incorporates a different internal strongback of equivalent robustness. As part of the MFFP certification, the containment boundary and impact limiter design passed, full-scale, a series of hypothetical accident condition (HAC) free and puncture drop tests. The licensed gross weight of the MFFP (14,130 lb) bounds the gross weight of the HUFP (14,000 lb). The MFFP is certified by NRC Certificate of Compliance (CoC) number 9295, Revision 0 (Package ID number USA/9295/B(U)F-96).[5] A combination of analytical modeling and full-scale testing has demonstrated that the HUFP satisfies the requirements of 10 CFR 71 and 49 CFR 173.

This SER documents the DOE PCP Staff review of the HUFP SARP. The Staff performed structural, thermal, shielding and criticality confirmatory analyses on the HUFP package design to validate compliance with regulatory requirements.[6, 7, 8, 9] PCP Staff did not perform any confirmatory analysis of the NRC-approved MFFP SARP bases. Given the NRC's review and approval of the MFFP SAR and PCP Staff review of the statements and representations in the HUFP SARP, the Staff has concluded that both the design and performance of the HUFP with the intended payloads meet the requirements of 10 CFR 71. Reviews of each SARP Chapter are documented herein.

Regulatory Changes

The set of regulations driving the HUFP design is the same as that which drove the "-96" certified MFFP design it is based on. No further discussion is necessary.

Because the SER for this package was prepared for a newly consolidated application, the review presented herein was performed using the methods outlined in the *Packaging Review Guide for Reviewing Safety Analysis Reports for Packagings*.[10]

References

[1] Fluor Hanford, Inc., *Hanford Unirradiated Fuel Package (HUFP) Safety Analysis Report for Packaging*, HNF-28554, Revision 2, P.O. Box 1000, Richland, WA (August 2008).

[2] Title 10, Code of Federal Regulations, Part 71 (10 CFR 71), *Packaging and Transportation of Radioactive Materials*.

[3] Title 49, Code of Federal Regulations, Part 173 (49 CFR 173), *Shippers General Requirements for Shipments and Packagings*.

[4] Fluor Hanford, Inc., *Safety Analysis Report for Mixed Oxide Fresh Fuel Package*, Revision 0, Docket No. 71-9295 (June 2004).

[5] Nuclear Regulatory Commission, *Certificate of Compliance for Radioactive Material Packages No. 9295*, Revision 1 for Package ID No. USA/9295/B(U)F-96, January 1, 2008.

[6] T.T. Wu, Dynamic Analysis of Hanford Unirradiated Fuel Package Subjected to Sequential Lateral Loads of 30-Foot Drop and 40-Inch Puncture, M-CLC-A-00335 (April 7, 2008).

[7] N.K. Gupta, *Confirmatory Thermal Analysis of Hanford Unirradiated Fuel Package (HUFP)*, M-CLC-A-00327, Westinghouse Savannah River Co., Aiken, SC, (December 2007).

[8] A.H. Bridges and R.L. Reed, *Shielding Analysis of the HUFP with DFA and IDENT-69G (U)*, N-CLC-A-00069, Revision 0, Washington Safety Management Solutions LLC (December 2007).

[9] A.H. Bridges and R.L. Reed, *Criticality Analysis of the HUFP with DFA and IDENT-69G (U)*, N-CLC-A-00070, Revision 0, Washington Safety Management Solutions LLC (December 2007).

[10] A.A. DiSabatino, et al., *Packaging Review Guide for Reviewing Safety Analysis Reports for Packagings*, UCID-21218, Revision 3, Lawrence Livermore National Laboratory (February 2008).

1. GENERAL INFORMATION REVIEW

This review includes an evaluation of the *Hanford Unirradiated Fuel Package (HUFP) Safety Analysis Report for Packaging (SARP)*[1-1] by DOE PCP Staff (the Staff) with respect to the requirements given in 10 CFR 71.[1-2] This chapter of the review addresses the design description and defining engineering drawings given in Chapter 1, of the HUFP SARP and the Contents as described in SARP Tables 1.2-1 through 1.2-8.

1.1 Areas of Review

The General Information Review includes those Areas of Review cited in the Packaging Review Guide.[1-3]

1.2 Regulatory Requirements

The requirements of 10 CFR 71 applicable to the General Information review of the HUFP are those cited in the Packaging Review Guide.[1-3]

1.3 Review Procedures

The following subsections describe the review methods for the Areas of Review applicable to the *General Information* chapter of the HUFP SARP documenting the packaging design and packaging payloads.

1.3.1 Introduction

1.3.1.1 Purpose of Application

The primary purpose of the Applicant's submittal is to document compliance of the new HUFP design (package model number USA/9905/B(U)F-96(DOE)) with current regulatory safety requirements for Type B packages in the United States. The HUFP is a new design adapted from the "-96" certified Mixed-oxide Fresh Fuel Package (MFFP) design.[1-4] Cross-linkage of federal regulations to the 1996 International Atomic Energy Agency regulations gave the MFFP its "-96" designation.

1.3.1.2 Summary Information

The Applicant designed the HUFP to transport payloads consisting of a core component container (CCC) containing unirradiated Driver Fuel Assemblies (DFAs) or loose fuel pins inside (within IDENT-69G containers). A CCC may house up to seven (7) DFAs or six (6) IDENT-69G containers loaded in excess of 20 Ci of plutonium. Drawing 41199-10, Sheet 1 of 1, Rev. 2, specifies mounting of a nameplate in accordance with 10 CFR 71.85(c). The Applicant designed the HUFP for an internal pressure of 25 psig with no pressure relief device, and Section 1.1 of the SARP specifies package type as B(U)F.

Section 1.1 of the SARP states that the package is designed to contain over 3000 A_2 resulting in a Category I designation, and Section 2.1.4 of the SARP cites the HUFP as a Category I package, per NUREG/CR 3854.[1-5] Section 1.1 of the SARP also identifies the corresponding HUFP design criteria as ASME B&PV Code Section III, Division 1, Subsection NB[1-6] and Subsection NG[1-7] for design, analysis, fabrication and examination. Additional discussion of applicable codes and standards is included in Chapters 2 through 9 of this SER.

Section 1.0 of the SARP states quality assurance meets the requirements of 10 CFR 71, Subpart H. Chapter 9 of the SARP explains the Applicant's QA program and its application to the HUFP.

The Applicant has specified a Criticality Safety Index for HUFP contents and the corresponding number of packages that may be shipped via single conveyance. Shipment of the HUFP must be by exclusive use conveyance.

1.3.1.3 Statement of Compliance

Section 1.1 of the SARP states that the HUFP design satisfies the regulatory requirements of 10 CFR 71.[1-2]

1.3.1.4 Summary of Evaluation

Section 1.1 of the SARP does not state compliance with specific 10 CFR 71 requirements, but rather states globally that the HUFP meets the applicable requirements of Subpart E (Package Approval Standards) and Subpart F (Package, Special Form, and LSA-III Tests) of 10 CFR 71. The section also cites Appendix 2.12.3 for detailed discussion of certification testing and notes that the HUFP and certified MFFP share common containment body and impact limiter designs.

Section 1.1 also cites Chapter 5 of the SARP for the HUFP shielding evaluation and states that the Transport Index does not apply to the HUFP, because criticality analyses given in Chapter 6 of the SARP resulted in a CSI of 100 that limits the HUFP shipments to one per conveyance.

1.3.2 Package Description

1.3.2.1 Packaging

Section 1.2 of the SARP describes the HUFP and Appendix 1.3.2 of the SARP provides the drawings defining the design. The HUFP includes an austenitic stainless steel cylindrical containment body and a closure lid that provide leaktight containment for payloads. The CCC houses the payload, and the CCC-Adapter is a structural strongback that locates the CCC within the containment body. The CCC and CCC-Adapter fit into the containment body and provide geometric control of the fissile material to ensure subcriticality. The HUFP design does not incorporate biological shielding of any kind. Opposite ends of the cylindrical containment body receive impact limiters prior to shipment. The impact limiters mitigate impact loads and provide thermal protection for the closure lid bolts and seals. Outfitted for shipment, the overall length and diameter of the HUFP are 201.33 inches and 60 inches, respectively, and the maximum shipping weight is 14,000 pounds. Transfer of payload heat to the ambient environment is passive.

The HUFP containment boundary consists of the containment body, closure lid and bolts (the containment structure -- cylindrical shell and bottom forging, sealing flange, the inner plate and sealing ring of the closure lid), main (middle) O-ring seal, vent-port plug and elastomeric seal washer and fill-port plug and elastomeric seal. SARP Figure 1.2-7 illustrates the major components of the HUFP containment boundary.

The HUFP design does not incorporate a pressure relief system or valves for venting the containment volume.

Section 1.2.1.1 of the SARP describes the containment body in detail. Section 1.2.1.4 of the SARP describes the impact limiters in detail. The HUFP does not include lifting or tie-down devices. Rather steel mounting bands clamp the HUFP containment body to support structures integral to a skid platform that mounts on the conveyance.

1.3.2.2 Contents

Section 1.2.2 of the SARP describes the HUFP payloads in detail. There are up to seven DFAs or up to six IDENT-69G containers. A DFA is an unirradiated mixed-oxide fuel assembly developed for service within the FFTF breeder reactor, and houses fuel pins securely within its duct body. An IDENT-69G container houses loose fuel pins and includes aluminum dunnage rods to limit the radial motion of the pins and baskets to limit axial motion. The fissile portion of the HUFP payload comes from the fuel pins.

Section 1.2 of the SARP defines four types of DFAs and nine categories of loose fuel pins. Individual fuel pellets are ceramic material clad by 316 stainless steel. Plutonium activity exceeds 20 Curies.

SARP Tables 1.2-1 and 1.2-2 list physical and nuclear parameters for the DFAs. The data include enrichment, dimensions, and cladding details. In addition, the SARP characterizes loose fuel pins into low- and high-reactivity groups. SARP Tables 1.2-4 and 1.2-5 list the bounding physical and nuclear parameters for the loose pins. Here too, the data include enrichment, dimensions, and cladding details. Table 1.2-6 presents the radionuclide inventory of a DFA, and Tables 1.2-7 and 1.2-8 present the radionuclide inventories of fuel pins and insulators, respectively.

Any of the seven locations within the CCC may receive a DFA, but DFAs and IDENT-69G containers must not be mixed with a CCC. However, IDENT-69G containers must be arranged as described in Section 1.4.2 of this SER.

Section 1.2.1.15 of the SARP states combustible and reactive gases will not be generated within the HUFP under NCT.

Section 1.2.2.4 of the SARP establishes the MNOP of the two payloads at 10 psig (design pressure is 25 psig).

1.3.2.3 Special Requirements for Plutonium

The Applicant has stated in Section 1.2.2 of the SARP that plutonium content is in solid form, thereby satisfying the 10 CFR 71.63.

1.3.2.4 Operational Features

Section 1.2.4 of the SARP states that HUFP operation is not complex and that the HUFP design drawings present all operational features. The section also states that Chapter 7 of the SARP also presents operational features and instruction in their use.

Appendices

1.3.3.1 Drawings

Chapter 1 of the SARP includes two Appendices described as follows.

Section 1.3.1, entitled *Nomenclature*, lists acronyms, abbreviations, relevant terminology and explanations or descriptions.

Section 1.3.2, *Packaging General Arrangement Drawings*, provides a listing of HUFP design drawings followed immediately by clearly legible B-sized (11” by 17”) versions of the drawings. The following drawings revisions were included in the SARP.

- 41199-10, 1 sheet, HUFP Assembly, Revision 2
- 41199-20, 6 sheets, HUFP Body Assembly, Revision 5
- 41199-30, 3 sheets, HUFP Impact Limiter, Revision 3
- 41199-40, 2 sheets, HUFP Core Component Container Adapter, Revision 4
- 41199-50, 10 sheets, HUFP Core Component Container, Revision 2

1.3.3.2 Other Information

SARP references are listed as footnotes on the page in which they are cited.

1.4 Evaluation Findings

1.4.1 Findings

Based on review of the statements and drawings given in the application, the Staff concludes that the general information chapter describes the HUFP design adequately and that the HUFP design meets the containment requirements of 10 CFR 71.

1.4.2 Conditions of Approval

In addition to a summary package description and specifications of authorized contents, the following other conditions of approval are applicable to the General Information review of the HUFP:

- The maximum gross weight of the HUFP may not exceed 14,000 lb;
- The maximum payload weight is 3300 lb (six IDENT-69G containers);
- The maximum decay heat per package may not exceed 400 watts (seven DFAs);
- The maximum decay heat per IDENT-69G container payload is 275 watts;
- The maximum decay heat per single IDENT-69G container is 75 watts;
- The CCC may be loaded with up to seven DFAs.
- DFAs and IDENT-69G containers shall not be mixed within a single CCC.
- The CCC loaded with IDENT-69G containers may be in one of two general loading configurations:
  - Low-reactivity CCC: Up to six (6) low-reactivity IDENT-69G containers, or
  - High-reactivity CCC: Up to three (3) low-reactivity IDENT-69G containers and one (1) high-reactivity IDENT-69G container.
- The CCC shall not be loaded with more that one high-reactivity IDENT-69G.
- Each low-reactivity IDENT-69G is limited to a maximum of 250 fuel pins.
- Each high-reactivity IDENT-69G is limited to a maximum of 150 fuel pins.
- Pin count is independent of pin length;
- The Criticality Safety Index is 100;
- The HUFP must be shipped by exclusive-use conveyance only.

SARP Section 1.3.2 presents the drawings that define the HUFP design.

1.5 References

[1-1] Fluor Hanford, Inc., *Hanford Unirradiated Fuel Package (HUFP) Safety Analysis Report for Packaging*, HNF-28554, Revision 2, P.O. Box 1000, Richland, WA (August 2008).

[1-2] Nuclear Regulatory Commission, 10 CFR Part 71, *Compatibility with IAEA Transportation Standards (TS-R-1) and Other Transportation Safety Amendments*; Final Rule, 69 F.R. 3698, pp. 3698–3814, January 26, 2004, as amended.

[1-3] A.A. DiSabatino, et al., *Packaging Review Guide for Reviewing Safety Analysis Reports for Packagings*, UCID-21218, Revision 3, Lawrence Livermore National Laboratory (February 2008).

[1-4] Nuclear Regulatory Commission, *Certificate of Compliance for Radioactive Material Packages No. 9295*, Revision 1 for Package ID No. USA/9295/B(U)F-96 (January 1, 2008).

[1-5] U.S. Nuclear Regulatory Commission, *Fabrication Criteria for Shipping Containers*, NUREG/CR-3854, Washington, DC (March 1985).

[1-6] American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, *Rules for Construction of Nuclear Power Plant Components*, Division 1, Subsection NB, Class 1 Components, 2001 Edition, 2002 and 2003 Addenda. More recent editions/addenda may be used for fabrication.

[1-7] American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, *Rules for Construction of Nuclear Power Plant Components*, Division 1, Subsection NG, Core Support Structures, 2001 Edition, 2002 and 2003 Addenda. More recent editions/addenda may be used for fabrication.

2. STRUCTURAL REVIEW

This section of the SER documents the review of Chapter 2, *Structural Evaluation*, of the *Hanford Unirradiated Fuel Package (HUFP) Safety Analysis Report for Packaging (SARP)*[2-1] by DOE PCP Staff (the Staff). The review includes an evaluation of the SARP with respect to the requirements specified in 10 CFR 71.[2-2]

The HUFP design is similar to the Mixed-Oxide Fresh Fuel Package[2-3] (MFFP). Both the HUFP and the MFFP contain the same containment body and impact limiters.

The HUFP package is intended to transport a single core component container (CCC) containing multiple unirradiated MOX driver fuel assemblies (DFAs) or unirradiated loose fuel pins (within IDNET-69G containers).

2.1 Areas of Review

The Structural review of the HUFP SARP includes those Areas of Review cited in the Packaging Review Guide (PRG).[2-4]

2.2 Regulatory Requirements

The regulatory requirements of 10 CFR 71 applicable to the Structural Review are those cited in the PRG.[2-4]

2.3 Review Procedures

The Structural review ensures that the package design has been adequately described and evaluated under regulatory events of Normal Condition of Transport (NCT) and Hypothetical Accident Conditions (HAC) to demonstrate sufficient structural integrity to meet the requirements of 10 CFR 71.

The Structural review is based in part on the descriptions and evaluations presented in the General Information and the Thermal Evaluation chapters of the application. Similarly, results of the structural review are considered in the review of all other sections of the application.

The information presented in the subsections below relate to the areas of review referenced in Section 2.1 of this SER.

2.3.1 Description of Structural Design

The SARP identifies the following components as contributing directly or indirectly to the structural integrity of the packaging:

- <u>Containment body</u> includes the closure lid, closure bolts, and containment body weldment (stainless steel);

- Core Component Container (CCC) supports the payload and provides structural stability for criticality control purposes;
- Core Component Container Adapter (CCC-Adapter) supports the CCC and provides structural spacing for criticality control; and
- Impact limiters attenuate free-drop impact loads and provide thermal protection of containment boundary O-rings during the HAC fire event.

Table 2.3-1 of this SER lists the Applicant's stated design criteria for major components of the HUFP. SER Table 2.3-2 lists the Applicant's stress and acceptance criteria for the structural components of the HUFP.

Table 2.3-1 Critical Component Design Criteria

Component	Design Information Source
Containment structures	Section III, Subsection NB, Class 1 in accordance with NUREG/CR-3854[2-5]and NUREG/CR-3019[2-6]
Containment fasteners	NUREG/CR-6007[2-7]
Containment boundary	Leaktight in accordance with ANSI N14.5
Criticality control structures	Section III, Subsection NG, core support structure in accordance with NUREG/CR-3854 and NUREG/CR-3019
Impact limiters	Closed-cell polyurethane foam; General Plastics Last-a-Foam® FR-3700 for Crash and Fire Protection of Nuclear Material Shipping Containers, General Plastics Manufacturing Company
Components composed of Type XM-19 and Type 304	Material properties obtained from ASME BPVC Section II Part D.
Nitrile® Stat-O-Seals	Parker Catalog pages contained in Appendix 2.12.11 of the HUFP SARP

Table 2.3-2 Critical Component Stress Limits and Acceptance Criteria

Component	Stress Limits and Acceptance Criteria
Containment structures	Consistent with R.G. 7.6 and ASME BPVC Section III Subsection NB-3000 and Appendix F
Containment fasteners	NUREG/CR-6007
Containment boundary	Provide post-event containment under NCT and HAC that is leaktight to less than 10^{-7} std cm^3/sec air as measured in accordance with ANSI N14.5
Criticality control structures	Consistent with ASME BPVC Section III Subsection NG-3000 and Appendix F Section F-1341.2
Impact limiters	Component stresses are allowed to exceed material's yield strength for all conditions. Assuming that all of the free-drop energy is absorbed in the impact limiters, the acceptance criterion is that contact between a package component, other than the impact limiters, and the unyielding surface does not occur during the free drop event.
Tie-down devices	Allowable stresses are limited to the material yield strength, consistent with the requirements of 10 CFR §71.45(b)

Additional features of each of the main HUFP component structures are summarized in the following paragraphs.

2.3.1.1 Design Features

The HUFP design under review is very similar to the certified Mixed-Oxide Fresh Fuel Package[2-8] (MFFP). The HUFP and MFFP designs incorporate common containment body and impact limiters.

The Applicant designed the HUFP (also known as "Model 9905") to contain payloads under loadings defined by regulatory Normal Conditions of Transport (NCT) and regulatory Hypothetical Accident Conditions (HAC).

Specifically, the HUFP is designed to:

- Withstand loads resulting from handling, transportation and accident events;
- Provide containment under NCT that is leaktight to less than 10^{-7} ref cm^3/sec air as measured in accordance with American National Standards Institute (ANSI) ANSI N14.5;[2-9]
- Provide containment under HAC events that is measurably leaktight after the events in accordance with ANSI N14.5 (leak rate less than 10^{-7} ref cm^3/sec air);
- Include a vent port on the closure for post-load leak-rate tests;
- Protect the containment from excess heat in a HAC fire event;
- Provide mechanical cushioning to prevent damage to the containment in the event of impact; and
- Accept a payload consisting of a CCC-Adapter containing mixed oxide (MOX) unirradiated driver fuel assemblies (DFAs) or loose unirradiated fuel pins (within IDENT-69G canisters).

2.3.1.2 Codes and Standards

The Applicant demonstrated HUFP structural performance by a combination of analytical evaluations and certification testing of a prototypic package. The prototypic package tested was the MFFP with the same containment boundary and impact limiters as the HUFP. The Applicant's acceptance criteria for analytical assessments are in accordance with Regulatory Guide 7.6[2-10] (R.G. 7.6) and Section III of the ASME Boiler and Pressure Vessel Code[2-11] (BPVC). The Applicant's acceptance criterion for certification testing of both free drop and puncture is demonstration that the containment boundary remains leaktight in accordance with ANSI N14.5 after the tests. In addition, package deformations determined from either testing or analysis must be within the bounds of the deformed geometry assumptions used in criticality and thermal analyses, or be otherwise validated.

SER Table 2.3-1 lists codes and standards the Applicant used in the design of critical components of the MFFP. SER Table 2.3-2 lists codes and standards the Applicant used for determination of stress limits and acceptance criteria. Details are discussed in the following subsections.

2.3.1.2.1 Containment Structures

The containment body is classified as a Section III, Subsection NB, Class 1 component in accordance with NUREG/CR-3854[2-5] and NUREG/CR-3019.[2-6] Containment material stress limits applied by the Applicant during analyses are consistent with R.G. 7.6 and the ASME BPVC, Section III, Subsection NB-3000, and Appendix F. The Applicant applied stress limits for containment fasteners in accordance with NUREG/CR-6007.[2-7]

The HUFP contents exceed 3,000A_2, and according to Table 1 of R.G. 7.11,[2-12] the HUFP is therefore a Category I package. In accordance with NUREG/CR-3854, the appropriate design criteria are in Section III, Subsection NB of the ASME BPVC, corresponding to the information given in Table 2.1 of the PRG.[2-4] Consequently, the Applicant based the design of the containment boundary on the methodology of R.G. 7.6, and applied and combined load cases according to R.G. 7.8.[2-13]

2.3.1.2.2 Criticality Control Structures

The HUFP criticality control structures are classified as Section III, Subsection NG, core support structures by NUREG/CR-3854 and NUREG/CR-3019. The Applicant evaluated the response of the HUFP criticality control structures to free-drop impacts under NCT by treating any permanent deformations that resulted under NCT as input for the subsequent HAC free-drop impact analysis. The Applicant's stress criteria for HAC are consistent with the ASME BPVC, Section III, Appendix F, Section F 1341.2.

2.3.1.2.3 Other Structures

Impact limiter component stresses are permitted to exceed the material's yield strength for all conditions. Assuming that all of the free-drop energy is absorbed within the impact limiters, the acceptance criterion is that contact of a package component (other than impact limiters) with the unyielding surface does not occur as part of the free-drop impact event.

The Applicant's evaluation of tie-down devices, limiting allowable stresses to the material yield strength, is consistent with the requirements of 10 CFR §71.45(b).

2.3.2 Materials of Construction

2.3.2.1 Material Specifications and Properties

The Applicant's structural analyses used temperature-dependent material of metallic components primarily from Section II Part D of the ASME BPVC.[2-14] Material properties were linearly interpolated or extrapolated from these tables as necessary. HUFP body components and closure lid are fabricated from Type XM-19 stainless steel. The closure-lid bolt material is ASTM A564, Grade 630, condition H1100 stainless steel. The CCC and the CCC-adapter components were fabricated primarily from Type 304 stainless steel as described in SARP Table 2.2-2. The fasteners used on CCC-adapter are of ASTM A574 alloy steel (socket-head cap screws). The impact limiter attachment bolts are ASTM A320, Grade L43 bolting material. The central trunnion at the bottom of the package is ASTM A479, UNS S21800. Threaded inserts that mate with the closure-lid bolts are austenitic stainless steel.

The Applicant selected and evaluated criticality control materials for the CCC and CCC-adapter to enable compliance with allowable limits specified in ASME BPVC, Section III, Subsection NG 3000,[2-15] and Appendix F. The materials must be in accordance with either ASTM or ASME standards. Regardless of the standard specified, the materials must exhibit the required structural attributes.

The impact limiter shells are Type 304 stainless steel. The primary energy absorbing material is closed-cell polyurethane foam cast-in-place within the impact limiter shells. The polyurethane foam within the top-end impact limiter has a nominal density of 10 lb/ft^3 and the foam within the bottom-end impact limiter has a nominal density of 11½ lb/ft^3. The material property data were developed in accordance with acceptance testing requirements outlined in SARP Section 8.1.5.1, *Polyurethane Foam*.

The HUFP design includes several non-structural materials. The vent, fill, and test-port plugs are ASTM B16, 360 alloy and half-hard brass, respectively, and sealed with butyl rubber seal washers. The closure-lid's three O-ring seals are also fabricated from butyl rubber. Nitrile Stat-O-Seals® seal the CCC closure lid but are not credited for containment. Brass covers protect the plugs, optionally sealed with Teflon® gaskets. The washers beneath the closure-lid bolts are hardened alloy steel.

With the exception of the closure-lid bolts and energy-absorbing foam, all structural components of the HUFP are austenitic stainless steels. Austenitic stainless steels do not undergo a ductile-to-brittle transition in the temperature range of interest (i.e., down to -40 °F) and need not be evaluated for brittle fracture. Further, Regulatory Guide 7.11[2-12] states,

> *"Since austenitic stainless steels are not susceptible to brittle failure at temperatures encountered in transport, their use in containment vessels is acceptable to the staff and no tests are needed to demonstrate resistance to brittle fracture."*

The closure-lid bolts are ASTM A564, Type 630, Condition H1100, precipitation hardened stainless-steel bolting materials. In accordance with Section 5 of NUREG/CR-1815,[2-16] bolts are not considered fracture-critical components, because multiple load paths exist and bolting systems are generally redundant, as is the case with the HUFP. Therefore, brittle fracture is not a failure mode of concern.

Packaging material specifications and corresponding HUFP components are summarized in Table 2.3-3.

Table 2.3-3 Components of the HUFP Design

Component	Material or Specification
Body	Type XM-19 SS
Closure lid	Type XM-19 SS
Closure bolts	ASTM A564 Grade 630 condition H1100 SS
Closure lid bolt washers	Hardened alloy steel
Threaded inserts used with closure bolts	Austenitic stainless steel
Containment (middle), inner and outer closure lid seals	O-ring, butyl rubber
CCC-adapter components	Primarily Type 304 SS
CCC-adapter Fasteners	ASTM A574 (alloy steel socket-head cap screw)
CCC components	Primarily Type 304 SS
CCC lid seal	Nitrile Stat-O-Seals,® no containment function claimed
Lid-end impact limiter	Closed-cell polyurethane foam, 10 lb/ft^3
Bottom-end impact limiter	Closed-cell polyurethane foam, 11.5 lb/ft^3
Impact limiter attachment bolts	ASTM A320, Grade L43
Impact limiter shells	Type 304 SS
Central trunnion	ASTM A479 UNS S21800
Vent, fill and test port plugs	ASTM B16, 360 alloy, half hard brass
Plug sealant	Butyl rubber seal washers
Plug covers	Brass covers with optional Teflon® gaskets
Payload	MOX unirradiated DFAs or loose fuel pins (within IDENT 69G canisters)

2.3.2.2 Prevention of Chemical, Galvanic or Other Reactions

The major materials of construction of the HUFP design (i.e., stainless steel, polyurethane foam, butyl rubber, brass, and alloy-steel fasteners) have no significant chemical, galvanic, or other reactions in air or water environments. Since galvanic reactions occur primarily in aqueous environments and loading/unloading of the HUFP must take place in a dry environment, galvanic reactions will not occur. Any exposure to water from rain would be short-term, and the outer surface of the packaging is entirely stainless steel, essentially non-reactive with water or any of the other packaging materials. The stainless steel shell of the impact limiters fully encases the polyurethane foam, making the foam inaccessible under normal conditions. The nitrile and butyl rubber seals are designed to interface with steel components, which are typical for their intended applications. Brass port-plugs and covers prevent galling with stainless steel. These materials have a favorable history of service in radioactive materials packagings designed for the transport of fresh fuel assemblies. Therefore, no significant chemical, galvanic or other reactions will arise, and the HUFP design meets the requirements of 10 CFR §71.43(d).

2.3.2.3 Effects of Radiation on Materials

Ionizing radiation has no significant effect on the structural materials of the HUFP. These materials have a favorable history of service in radioactive materials packagings designed for the transport of fresh fuel assemblies. Therefore, no significant radiation effects will arise, and the HUFP design meets the requirements of 10 CFR §71.43(d).

2.3.3 Fabrication, Assembly, and Examination

2.3.3.1 Fabrication and Assembly

The Staff has confirmed that the Applicant has prescribed appropriate fabrication specifications via codes or standards, and that either the HUFP's engineering drawings or the text of the SARP identify the applicable code or standard properly. For the containment components, fabrication meets the requirements of the ASME BPVC, Section III, Subsection NB.

2.3.3.2 Examination

The Staff has confirmed that examination methods and acceptance criteria are dictated by the same code or standard cited for fabrication of a component.

2.3.4 General Considerations for Structural Evaluations

The Applicant's structural evaluation of the HUFP credits full-scale testing of prototype MFFPs that are slightly heavier than the HUFP. The Applicant supplemented the testing program with analyses extrapolating test conditions to other NCT and HAC events and to show that the results from MFFP testing bounded those obtainable from testing a full-scale HUFP. Confirmatory analyses support the Applicant's assertions.

2.3.4.1 Evaluation by Test

- The Staff considered the description of the surface (e.g., material, mass and dimensions) used for the free-drop impacts and confirmed that it is an essentially unyielding surface as specified in §71.73(c)(1).
- The Staff considered the description of the solid-steel "puncture pin" (e.g., material, dimensions, orientation and method of mounting) used for the puncture test and confirmed that it was securely attached to an essentially unyielding surface, has sufficient length to cause maximum damage to the package and meets the other specifications of §71.73(c)(3).
- The Staff identified differences between the materials and structure of the MFFP compared to the HUFP. The Applicant evaluated the effects of these differences in the SARP.
- The Staff noted that the weight of the MFFP exceeds the weight of the HUFP.
- The Staff verified that the Applicant's selected drop/impact orientations are consistent with maximum damage expectation and that the selections are justified.

- The Staff verified that the Applicant evaluated all test results and interpreted associated implications, including both interior and exterior damage of the test article. As the internals of the MFFP differ somewhat from the HUFP, the Applicant evaluated both interior and exterior damage of the HUFP via finite element analyses.
- The Staff evaluated the photographs included in the SARP that documented regulatory testing of the MFFP. The Staff did not evaluate video recordings of the tests performed on the MFFP.
- The Staff verified that the Applicant evaluated the margin of safety of the HUFP design satisfactorily. The Applicant demonstrated the margin of safety through repetition of tests on each test article. Performing multiple 30-ft drop tests on the same test article is not required by the codes and standards
- The Staff addressed the criteria for evaluating pass/fail of the regulatory tests. The Applicant compared test results with these criteria.
- The Staff found that the greatest localized plastic strain in the containment vessel test-article resulted from the puncture drop-test impact at mid-length of the package. Confirmatory analysis determined the margin to rupture of the HUFP containment vessel.

2.3.4.2 Evaluation by Analysis

For cases where the evaluation by testing was not applicable to the HUFP or in instances where the applicant supplemented the tests, the Staff evaluated results of analyses including hand calculations and drop simulations.

- The Staff verified that the Applicant provided a clear description of the calculations and all assumptions.
- The Staff verified that the Applicant's models and material properties were appropriate for the load combinations considered, that the material properties (e.g., elastic, inelastic) were consistent with the analysis methods, that the application justified the strain rate at which the properties were determined and that the analysis considered true stress-strain or engineering stress-strain, as applicable.
- The Staff has confirmed that the Applicant performed bounding dynamic analyses.
- The Staff is satisfied that the Applicant selected the most unfavorable drop/impact orientations for the simulated 30-ft drop events.
- The Staff verified that where applicable, the Applicant benchmarked and used computer codes appropriately.
- The Staff verified that the Applicant evaluated the response of the package to loads and the structural stability of individual members, as applicable, in terms of stress and strain to components and structural members.

- The Staff examined the Applicant's summary results tables, compared the results with the acceptance criteria provided, verified that the acceptance criteria were met and the criteria are in accordance with appropriate codes and standards. Several results did not meet general acceptance criteria for containment components because of conservative analysis assumptions. These instances are addressed in Sections 2.3.6.7 and 2.3.7.1 of this SER.
- Where the Applicant's analysis results exceeded acceptance criteria for bolting, the Staff's bases bolting acceptance on results from the stringent test program where each test article was subjected to multiple 30-ft drop impacts. Regulations require only one 30-ft drop test per test article. In testing, only one of 24 bolts failed in one test article, and in that case, the test article remained leaktight. Therefore, acceptance of the bolts is based on testing rather than analytical results.

2.3.5 Lifting and Tie-Down Standards for All Packages

2.3.5.1 Lifting Devices

The HUFP design does not incorporate lifting devices into the structural part of the package.

2.3.5.2 Tie-Down Devices

The HUFP design includes doubler plates that assist with tie-down operations. These doubler plates are a structural part of the package. The Applicant's evaluation of tie-down devices limits allowable stresses to the material yield strength, consistent with the requirements of 10 CFR §71.45(b).

2.3.6 Evaluation for Normal Conditions of Transport

2.3.6.1 Heat

If exposed to direct radiation at 100°F ambient temperature, the containment body will reach maximum temperature of 171°F, the closure lid and closure bolts will reach 146°F, the CCC will reach 402°F (near the mid-height of its longitudinal axis), and the CCC-Adapter will reach 221°F (near the mid-height of its longitudinal axis).

- The Applicant set design temperatures conservatively at 175°F for the containment body, 160°F for the closure lid and bolts, 405°F for the CCC large tubes, 200°F for the CCC small tubes, and 225°F for the CCC-Adapter. These design temperatures are consistent with the NCT thermal results documented in SARP Table 3.1-1.
- The Staff verified that the Applicant evaluated differential thermal expansions and possible geometric interferences and confirmed that none are significant.

2.3.6.2 Cold

For the cold condition, a -40°F steady state ambient temperature is utilized per 10 CFR §71.71(c)(2), with zero insolation and zero decay heat. This condition results in a uniform temperature of -40°F throughout the HUFP.

- HUFP temperatures under the cold test condition are consistent with those documented in Section 3.3.1.2.

- The HUFP SARP requires the payload to be dry. Hence, the HUFP contains no liquids that could freeze or otherwise adversely affect the package under the -40°F condition.
- The -40°F condition does not adversely affect the HUFP materials of construction, including brittle fracture.
- The closure-bolt preload force at -40°F is more than 75% of the minimum room temperature preload force. Thus, the closure is secure at reduced temperatures.

2.3.6.3 Reduced External Pressure

Reducing the external pressure to 3.5 psia combined with maximum internal pressurization could cause increased pressure loading on the containment body walls.

- The Applicant's analysis of the HUFP under an internal pressure differential of 25 psi bounds the possible effects of reduced external pressure under NCT.

2.3.6.4 Increased External Pressure

Increased external pressure to 20 psia combined with minimum internal pressurization could cause localized buckling of the containment body shell.

- The Applicant's buckling analysis of the containment body per ASME Code Case N-284[2-17] for an external pressure differential of 20 psi demonstrated that the loading condition will not buckle the containment body shell.
- The Applicant evaluated the package design adequately for the effects of increased external pressure equal to 140 kPa (20 psi) absolute. In the evaluation, the Applicant considered this and more severe loading conditions for the possibility of buckling.

2.3.6.5 Vibration

The Applicant performed a random vibration analysis based on Draft ANSI N14.23[2-17] to demonstrate that vibration and shock loadings are small and would not cause any fatigue concerns. The Applicant used Design Fatigue curves from Figure I-9.2.2 and Table I-9.2.2 of the ASME code Section III, Appendix I for XM-19 SS shell material in the analysis, and calculated a margin of safety of +7.2. Therefore, the Applicant evaluated the package design adequately for the effects of vibration normally incident to transport.

2.3.6.6 Water Spray

HUFP materials of construction are impervious to the water spray test identified in 10 CFR §71.71(c)(6). Water spray would not damage the containment body since moisture does not adversely affect stainless steel.

2.3.6.7 Free Drop

The Applicant states that a free drop of the HUFP through a distance of three feet onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected, would not reduce the effectiveness of the packaging. This assertion is based on favorable results from full scale testing of the MFFP. The Applicant discussed the MFFP test results, showing that they bound those obtainable from testing the HUFP.

In the discussion of dynamic non-linear finite element analysis documented in Section 2.12.5 of the HUFP SARP,[2-1] the Applicant reported three instances in which stresses exceeded the primary membrane stress limit of containment vessel components under NCT. These instances include a small area of high bearing stress on the bottom outer surface of the HUFP bottom plate from the NCT side drop and portions of the closure lid and the lid-bolting flange, all under the NCT center-of-gravity-over-closure-lid end drop. In these cases, the Applicant's comparison of peak stresses with the primary membrane stress limit is conservative. In each case of overage, the Applicant carried out detailed analysis of the region to show that the stress in question was not a primary membrane stress and that it met applicable limits.

2.3.6.8 Corner Drop

According to 10 CFR §71.71(c)(8), this test is not required for the HUFP, because the total weight of the package exceeds 220 lb.

2.3.6.9 Compression

According to 10 CFR §71.71(c)(9), this test is not required for the HUFP, because the total weight of the package exceeds 11,000 lb.

2.3.6.10 Penetration

The Staff agrees with the assertion in the application that the 40-inch drop of a 13-pound, hemispherical-head, 1½-inch diameter, steel cylinder, as defined in 10 CFR §71.71(c)(10), is bounded by the case of a 40-inch drop of the entire package onto a puncture bar.

2.3.6.11 Structural Requirements for Fissile Material Packages

The structural analyses documented in the SARP demonstrate compliance with the following conditions for fissile material packages:

- The geometric form of HUFP contents is not altered substantially by NCT events.
- The HUFP containment system precludes the in-leakage of water following NCT and HAC events.
- NCT events do not reduce the total effective volume of the HUFP, on which nuclear criticality safety is assessed, by more than 5%.
- NCT events do not reduce the total effective spacing between fissile contents and the outer surface of the package by more than 5%.
- HAC events do not produce an opening in the outer surface of the HUFP large enough to pass a 10-cm cube. Given that the outer surface of the MFFP is identical to the outer surface of the HUFP and the MFFP weighs more than the HUFP, the Staff concludes that the results from the tests on the MFFP are bounding for this criterion.

2.3.7 Structural Evaluation for Hypothetical Accident Conditions

2.3.7.1 Free Drop

- The Applicant evaluated the structural integrity of the HUFP against 30-ft drop events by comparison to a similar package, the MFFP, with augmentation by finite element analyses.
- The Applicant credited experimental evaluation of the structural integrity of the HUFP against regulatory 30-ft drop events by citing testing of the similar MFFP design. The MFFP drop tests were performed at the Coyote Canyon Aerial Cable Facility at the Sandia National Laboratory (SNL) reservation. The essentially unyielding impact surface was constructed from a 4-inch to 8-inch thick steel armor plate, embedded into a two-million pound drop-pad structure. The impact target weighs approximately 13,800 lb. The capacity of SNL's drop-test facility for regulatory 30-ft free-drop testing is 50,000 lb – several times the mass of the MFFP.
- Credit for HAC drop-testing of the HUFP, comes from the results of four 30-ft drop tests performed on the MFFP. The four 30-ft drop tests were in the following orientations: horizontal, center-of-gravity-over-corner (CGOC), 15° slap-down with the closure lid impacting first and 15° slap-down with the closure lid impacting second. These tests were performed with chilled (minimum -20°F) impact limiters. The MFFP body was at ambient temperature in all cases except for Test Series 1 (consisting of a horizontal 30-ft drop followed by three puncture impacts from different puncture-drop orientations) in which the MFFP body was chilled (minimum -20 °F).
- The Applicant selected two orientations for impact analysis most likely to affect either criticality control or containment. The side-drop impact is most likely to reconfigure the long relatively slender CCC tubes, thereby affecting criticality control and may cause seal area deformations that could affect containment. However, the end (80° CGOC) drop impact is more likely to cause seal area deformations that could affect containment. The Applicant benchmarked the models impact analyses against accelerometer results obtained from the certification testing of the MFFP as documented in Appendix 2.12.3 of the HUFP SARP.
- Acceptability of HUFP damage from 30-ft drop impacts is based on these four MFFP tests under regulatory cold temperature conditions and corroborating finite element analysis of the HUFP in the worst-case orientations under regulatory hot environmental conditions.
- Section 2.12.5 of the HUFP SARP documents dynamic non-linear finite element analysis. In two cases, the Applicant reported stresses in excess of the primary membrane stress limit for containment vessel components from the CGOC impact.
  - A small portion of the closure-lid bolting flange adjacent to a bolt hole exceeded the stress limit. As in the NCT analysis, the Applicant compared peak stresses conservatively to the primary membrane stress limit. The Applicant provided detailed analysis of the region to show the stress in question was not a primary membrane stress and the applicable limits were met.

- – A single bolt opposite the impact point exceeded the stress limit. The stress in this bolt was about 2 ksi greater than the allowable but remained below the yield point. See Section 2.3.4.2 of this SER for further discussion bolt stress evaluation.

- The Staff performed confirmatory analysis of the HUFP subjected to regulatory impacts to evaluate cumulative damage from the 30-foot free-drop side impact followed by a 40-inch free-drop, side-puncture impact.[2-18] The results confirmed that the maximum values of general and local primary membrane stress intensities within the HUFP containment vessel are both within the allowable limits for the Level D service load defined in the ASME Code, Section III, Appendix F. In addition, the results show that the maximum value of cumulative equivalent plastic strains in the walls of the HUFP containment vessel is 0.075. This value is less than the effective strain corresponding to ultimate strength of XM-19 stainless steel, assumed conservatively to be 0.35.

2.3.7.2 Crush

Subpart F of 10 CFR 71 requires dynamic crush testing in accordance with the requirements of 10 CFR §71.73(c)(2). However, since the weight of the HUFP exceeds 1,100 pounds, the dynamic crush test is not required.

2.3.7.3 Puncture

Subpart F of 10 CFR 71 requires puncture testing in accordance with the requirements of 10 CFR §71.73(c)(3). By comparison of the HUFP to the MFFP, the Applicant credited acceptable regulatory puncture testing of the MFFP. The Applicant selected the side-drop orientation for the maximum possible damage. The Applicant further demonstrated the ability of the HUFP to withstand the puncture-drop impact by comparing analytical results to the results of six full-scale puncture tests of MFFP.

Confirmatory analysis of the puncture drop impact is described in Section 2.3.7.1 of this SER.

2.3.7.4 Thermal

10 CFR §71.73(c)(4) requires incorporation of worst-case damage from the 30-foot free-drop and puncture tests into the HAC fire event. SARP Section 3.4 presents this thermal evaluation of the HUFP under HAC.

2.3.7.5 Immersion—Fissile Material

Subpart F of 10 CFR 71 requires performing an immersion test of fissile-material packages in accordance with the requirements of 10 CFR §71.73(c)(5). The criticality evaluation presented in Chapter 6.0 assumes optimum hydrogenous moderation of the contents, thereby conservatively addressing the effects and consequences of water in-leakage.

2.3.7.6 Immersion—All Packages

Subpart F of 10 CFR 71 requires performing an immersion test of all packages in accordance with the requirements of 10 CFR §71.73(c)(6). For the HUFP, this external pressure condition is bounded by the requirements of 10 CFR §71.61, requiring the undamaged containment system to withstand an external water pressure of 290 psi for a period of not less than one hour without collapse, buckling, or in-leakage of water. SARP Section 2.7.7 demonstrates that the HUFP meets the requirements of 10 CFR §71.61, and correspondingly, the requirements of 10 CFR §71.73(c)(6).

2.3.8 Structural Evaluation of Special Pressure Conditions

HUFP payloads do not include irradiated nuclear fuel.

2.3.8.1 Special Requirement for a Type B Packages Containing More Than 10^5 A_2

Subpart E of 10 CFR 71 specifies performance of a deep immersion test in accordance with the requirements of 10 CFR §71.61. Since the HUFP payload can include more than 10^5 A_2 of any isotope, the Applicant evaluated buckling of the HUFP containment vessel under the 200-meter deep immersion test. The evaluation credited ASME Code Case N-284-1[2-17] and considered an external pressure of 290 psig, exceeding the pressure of 200 meters of water.

Consistent with R.G. 7.6 philosophy, the Applicant applied a factor of safety corresponding to ASME BPVC Service Level D conditions for HAC pressure loading. In this case, the applicable factor of safety is 1.34 for accident conditions, as specified in ASME BPVC Case N-284-1.

The SARP provides buckling geometry parameters and stresses. The buckling analysis assumes a conservative HUFP shell temperature of 175°F. Stresses were determined using the external pressure of 290 psi. All the interaction check parameters are less than unity, as required by the ASME BPVC Case N-284-1. Therefore, the HUFP shell will not buckle under deep immersion.

The same analytical methods presented in SARP Section 2.6.1.3.1, *Primary Stress Calculation*, for determining stresses from the 25-psig design pressure, are applicable for the 290 psig deep-immersion pressure. Since the stress behavior here is linear, stress results from SARP Section 2.6.1.3.1 can be simply multiplied by the ratio of 290/25 = 11.6. Given the HUFP containment design temperature of 175°F, the allowable primary membrane stress for Type XM-19 stainless steel is the lesser of 2.4Sm and 0.7Su, or 69,685 psi. The allowable primary membrane-plus-bending stress of Type XM-19 stainless steel is the lesser of 3.6Sm and Su, or 99,550 psi. Hence, the minimum margin of safety for stresses in the bottom closure plate, closure lid and shell is +1.96.

2.3.8.2 Analysis of Pressure Test

The Staff evaluated, by analysis, the response of a separate, undamaged containment system specimen subjected to 125% of its design pressure and found it acceptable. The Staff's evaluation is supported by the Applicant's determination of a margin of safety of +16.1 for stress analysis at the design pressure.

2.3.9 Appendices

Chapter 2 of the SARP includes eleven Appendices providing background calculations and other appropriate supplemental information as follows.

Section 2.12.1, entitled *Impact Limiter Evaluation*, provides details of the evaluation.

Section 2.12.2 entitled *Certification Test Plan*, provides details of the MFFP full-scale HAC impact test plan.

Section 2.12.3, entitled *Certification Test Results*, provides details of the full-scale MFFP HAC impact testing activities and results.

Section 2.12.4, entitled *Engineering Test Results*, provides details of half-scale test unit investigation of specific design features of the HUFP.

Section 2.12.5, entitled *Finite Element Structural Analysis*, provides details of the analytical models and analysis demonstrating that HUFP containment boundary and criticality control structures meet applicable requirements for NCT and HAC fee-drop impact events.

Section 2.12.6, entitled *CASKDROP Computer Program*, documents the methodology employed by the PacTec Proprietary computer program CASKDROP.

Section 2.12.7, entitled *Impact Limiter Weld Joint Test Results*, documents weld joint test results.

Section 2.12.8, entitled *Effect of Bounding Weight on Package Structural Responses*, provides detail of this examination.

Section 2.12.9, entitled *Application of the MFFP Certification Testing to the HUFP*, provides logic used in comparing the two packages.

Section 2.12.10, entitled *Buckling Evaluations Utilizing ASME BPVC Case N-284-1*, provides detail of the HUFP containment vessel bucking evaluation based on the Code case.

Section 2.12.11, entitled *Seal Washer Product Information*, lists the manufacturers engineering data.

2.4 Evaluation Findings

2.4.1 Findings

Based on review of statements and representations given in the HUFP SARP, the Staff concludes that the Applicant has described and evaluated the structural design adequately and that the package has adequate structural integrity to meet the requirements of 10 CFR 71.

The Staff approves the HUFP bolting analysis based on the Applicant's rigorous testing of each test article subjected to multiple 30-ft drop impacts. In testing, only one of 24 bolts failed in one test article, and in that case, the test article remained leaktight. Simplified bolt modeling assumptions within dynamic impact analysis documented in SARP Section 2.12.5 also led to uncertainty in the accuracy of the Applicant's results. Therefore, acceptance of the bolts is based on testing rather than analytical results.

2.4.2 Conditions of Approval

Approval of this application does not require special structural conditions.

2.5 References

[2-1] Fluor Hanford, Inc., *Hanford Unirradiated Fuel Package (HUFP) Safety Analysis Report for Packaging*, HNF-28554, Revision 2, P.O. Box 1000, Richland, WA (August 2008).

[2-2] U.S. Nuclear Regulatory Commission, 10 CFR Part 71, *Compatibility with IAEA Transportation Standards (TS-R-1) and Other Transportation Safety Amendments*; Final Rule, 69 F.R. 3698, pp. 3698–3814, January 26, 2004, as amended.

[2-3] Nuclear Regulatory Commission*, Certificate of Compliance for Radioactive Material Packages No. 9295*, Revision 1 for Package ID No. USA/9295/B(U)F-96, January 1, 2008.

[2-4] A.A. DiSabatino, et al., *Packaging Review Guide for Reviewing Safety Analysis Reports for Packagings*, UCID-21218, Revision 3, Lawrence Livermore National Laboratory (February 2008).

[2-5] L.E. Fischer, W. Lai, *Fabrication Criteria for Shipping Containers*, NUREG/CR-3854 (UCRL-53544), U.S. Nuclear Regulatory Commission (March 1985).

[2-6] R.E. Monroe, H.H. Woo and R.G. Sears, Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials, NUREG/CR-3019 (UCRL-53044) (March 1985).

[2-7] G.C. Mok, L.E. Fischer and S.T. Hsu, *Stress Analysis of Closure Bolts for Shipping Casks*, NUREG/CR-6007 (UCRLED-110637), U.S. Nuclear Regulatory Commission (April 1992).

[2-8] Nuclear Regulatory Commission*, Certificate of Compliance for Radioactive Material Packages No. 9295*, Revision 1 for Package ID No. USA/9295/B(U)F-96, January 1, 2008.

[2-9] American National Standards Institute Inc., *Leakage Tests on Packages for Shipment*, ANSI N14.5 (1997).

[2-10] U.S. Nuclear Regulatory Commission, *Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels*, Regulatory Guide 7.6, Revision 1, Washington, DC (March 1978).

[2-11] American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section III, *Rules for Construction of Nuclear Power Plant Components*, 2001 Edition, 2002 and 2003 Addenda.

[2-12] U.S. Nuclear Regulatory Commission, Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Maximum Wall Thickness of 4 Inches (0.1 m), Regulatory Guide 7.11 (June 1991).

[2-13] U.S. Nuclear Regulatory Commission, *Load Combinations for the Structural Analysis of Shipping Casks for Radioactive Material*, Regulatory Guide 7.8, Revision 1 (March 1989).

[2-14] American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section II, *Materials, Part D – Properties*, New York, 2001 Edition, 2002 and 2003 Addenda

[2-15] American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section III, *Rules for Construction of Nuclear Power Plant Components*, Division 1, Subsection NG, *Core Support Structures*, 2001 Edition, 2002 and 2003 Addenda.

[2-16] W.R. Holman, R.T. Langland, Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers Up to Four Inch Thick, NUREG/CR-1815, UCRL-53013 (August 1981).

[2-17] American Society for Mechanical Engineers Boiler and Pressure Vessel Code, Section III. Rules for Construction of Nuclear Power Plant Components, Case N-284-1, Metal Containment Shell Buckling Design Methods, Section III, Division 1, Class MC, 2001 Edition, 2002 and 2003 Addenda.

[2-18] American National Standards Institute, Inc., Design Basis for Resistance to Shock and Vibration of Radioactive Material Packages Greater Than One Ton in Truck Transport, ANSI N14.23, (1980).
[2-19] T.T. Wu, Dynamic Analysis of Hanford Unirradiated Fuel Package Subjected to Sequential Lateral Loads of 30-Foot Drop and 40-Inch Puncture, M-CLC-A-00335 (April 7, 2008).

3. THERMAL REVIEW

This section of the SER documents the review of Chapter 3, *Thermal Evaluation*, of the *Hanford Unirradiated Fuel Package (HUFP) Safety Analysis Report for Packaging (SARP)*[3-1] by DOE PCP Staff (the Staff). The review includes an evaluation of the SARP with respect to the requirements specified in 10 CFR 71.[3-2]

3.1 Areas of Review

The Thermal review of the HUFP SARP includes the Areas of Review given in the Packaging Review Guide.[3-3]

3.2 Regulatory Requirements

Regulatory requirements of 10 CFR 71 applicable to the Thermal review are those cited in the Package Review Guide.[3-3]

3.3 Review Procedure

The HUFP SARP includes the information essential for a thermal evaluation including drawings and the content decay heat. Of particular importance is the response of the containment vessel and associated O-rings, the shielding, and the contents of the HUFP to the imposed NCT (10 CFR 71.71) and HAC (10 CFR 71.73).[3-2]

3.3.1 Description of Thermal Design

3.3.1.1 Design Features

The applicant described the packaging components that control the response of the HUFP to the regulatory thermal environment. Section 1.2.1 of the SARP describes the containment shell, core component container (CCC), CCC adapter, and the impact limiters in sufficient detail for the thermal evaluation of the HUFP.

The primary design features intended to protect the HUFP from structural damage and overheating are the following.

- Two impact limiters, one on each end of the containment body shell, protect against impact and insulate against fire conditions. The impact limiter consists of Type 304 stainless steel casing filled with energy-absorbing rigid polyurethane foam that also insulates thermally during hypothetical accident events.

- The containment shell fabricated from Type XM-19 austenitic stainless steel serves as a pressure vessel with a closure lid and forms the containment system of the package. Three O-rings form a leaktight seal for containment vessel closure (inner O-ring, main ⅜-inch diameter bore-type O-ring, and an outer O-ring). The inner O-ring and the outer O-ring are present only to facilitate leakage rate testing. The containment boundary consists of the containment body shell, the closure lid, middle O-ring and the leak-test port plug and vent port plug.

The CCC houses all contents and is itself housed securely within a CCC adapter. The CCC can accommodate up to seven unirradiated MOX driver fuel assemblies (DFAs) or up to six IDENT-69G canisters containing loose fuel pins. The CCC consists of six A269 or A511, Type 304 stainless steel tubes arranged around a seventh tube of the same material. The tubes are welded to plates at the top and bottom. The top plate design includes one Nitrile O-ring in conjunction with an aluminum-jacketed metallic seal and twelve Parker Stat-O-Seals under bolt heads to prevent leakage from the closure. The CCC is supported inside a CCC adapter which in turn is secured inside the containment body shell to provide geometrical stability and facilitate heat transfer during NCT.

3.3.1.2 Decay Heat of Contents

The applicant has limited the maximum content decay heat rate for the HUFP to 400 watts associated with an intact DFA payload. The decay heat rate of 275 watts is associated with six IDENT-69G containers. Since the IDENT-69G houses loose pins, the Applicant evaluated an asymmetrical decay heat rate of 75 watts in an individual container. This review considers the maximum allowable decay heat rate of 400 watts.

3.3.1.3 Codes and Standards

The pressure vessel materials used in the HUFP design conform to Section III of the ASME B&PV Code.[3-4] The non-pressure component materials conform to ASTM standards cited in the SARP Chapter 3. The rigid polyurethane foam trademarked as Last-A-Foam™ is manufactured by General Plastics Manufacturing Company and is a material proven for its thermal insulating and mechanical shock absorbing properties. The CCC is fabricated from ASTM Type 304 stainless steel. The ASME and ASTM standards and General Plastics all specify the temperature design limits for these materials.

3.3.1.4 Summary Tables of Temperatures

Tables 2.12.5-1 and 3.1-1 of the SARP present the maximum temperatures attained by HUFP components under NCT and HAC. Section 2.6.1.1 of the SARP specifies the design temperatures used in the structural evaluation. The design temperatures are compatible with the maximum component temperatures.

The minimum temperature is –40°C based on the assumption that the package is shaded from insolation and without content heat generation.

Table 3.3-3 of the SARP presents for a DFA payload the maximum temperatures within HUFP components during NCT, both with and without insolation. Table 3.3-4 of the SARP provides similar data for the IDENT-69G payload. For a shaded 100°F environment, the maximum accessible surface temperature of the HUFP is below the limit of 185°F allowed for exclusive-use shipments.

Table 3.4-1 of the SARP presents the maximum temperatures within HUFP components during an HAC fire event. The post-fire cool-down did include insolation. These temperature values are associated with a 400-watt content decay heat rate and the higher of the undamaged or the damaged HUFP analyses. The temperatures of the containment body shell components reach their maxima two hours after cessation of the fire. Except for the CCC, the maximum temperatures of all components bound the post-fire steady state temperatures shown in Figures 3.4-6 and 3.4-7 of the SARP. The post-fire steady state temperature of the CCC under HAC is 15ºF higher than under NCT and well below its design limit. Maximum temperatures of HUFP components under HAC are below their design temperature limits.

3.3.1.5 Summary Table of Maximum Pressures

Table 3.1-2 of the SARP presents the maximum pressures within the HUFP. Calculated pressures in the HUFP under NCT and HAC are given in Tables 3.3-5 and 3.4-2, respectively, and are based on the average gas temperatures inside the containment body shell. The applicant set the HUFP MNOP at a conservative value of 10 psig to bound the calculated value of 3.4 psig. The applicant used a design pressure of 25 psig for evaluating the packaging structure under NCT. The applicant set the HUFP design pressure under HAC at a conservative value of 130 psig relative to a calculated value of 18.5 psig. These design pressures are identical to those used in the stress calculations discussed in Sections 2.6 and 2.7 of the SARP.

The applicant set temperatures within the HUFP prior to the HAC fire event based on NCT without insolation. In contrast, the temperatures for the MNOP calculation were developed from regulatory insolation on the package surface.

3.3.2 Material Properties, Temperature Limits and Component Specifications

3.3.2.1 Material Properties

Section 3.2 of the SARP presents the required thermal properties for all materials used in the fabricated HUFP. The temperature dependence of pressure and load bearing materials is well represented in the various tables. The references for the emissivity and absorptivity data are from well known sources and based on practical data.

3.3.2.2 Temperature Limits

Table 3.1-1 of the SARP presents design temperature limits for the containment body shell, CCC, O-rings and the rigid polyurethane foam. Different temperature limits for NCT and HAC are listed where applicable. Temperature limits for the O-rings are listed both for the short term (HAC) service and long term (NCT) service. Minimum temperature limits for the various component materials described in Section 3.2.2 of the SARP comply with the-40ºF (-40ºC) requirements.

3.3.2.3 Component Specifications

Section 3.2.2 of the SARP presents component specifications for the containment body shell, rigid polyurethane foam insulation, impact limiter shell, CCC components, and the CCC-

Adapter. Included among the component specifications are temperature limits for the pressure vessel, polyurethane foam insulation and temperature limits for the butyl rubber O-rings that seal the CCC closure. Component specifications also include pressures possible during NCT and HAC.

3.3.3 General Considerations for Thermal Evaluations

The Applicant evaluated the HUFP design by analysis and by comparison with certified Mixed-Oxide Fresh Fuel Package[3-5] that uses the same containment body shell and the impact limiters. The MFFP design was evaluated by analysis only. Comparison of the HUFP design with the performance of a similar certified package is a credible and reliable method of evaluation. The applicant's evaluation included initial conditions and thermal loadings that meet the regulatory requirements. The evaluation considered package orientations under appropriate normal and accident conditions to ensure that critical components are subjected to the most challenging loading conditions. The applicant applied thermal loadings conservatively to address any uncertainties.

3.3.3.1 Evaluation by Test

The Applicant did not evaluate the HUFP thermal design by testing under either NCT or HAC. Instead, Section 3.3.3.2 of the SARP documents evaluation by analysis and by comparison with the certified Mixed-Oxide Fresh Fuel Package[3-5] (MFFP) that uses the same containment body shell and the impact limiters.

3.3.3.2 Evaluation by Analysis

The Applicant performed three dimensional thermal evaluations of the HUFP under NCT and HAC using the finite element code SINDA/FLUINT with the pre- and post-processing software package Thermal Desktop. The thermal properties specified for the payload, packaging materials, insulation, and air are appropriate for thermal analyses of the HUFP. Expressions for the various modes of heat transport at the package boundaries are appropriate. Appendix 9.19.3 of the SARP describes the SINDA/FLUINT and Thermal Desktop. The appendix also lists material properties, convection coefficients, radiation surface properties, and internal and solar heat-source data input to Thermal Desktop. Appendix 9.19.3 of the SARP describes verification and validation of SINDA/FLUINT.

Appendices 3.5.1 and 3.5.2 of the SARP describe analyses of the undamaged HUFP under both NCT and HAC fire. Analysis of the damaged HUFP incorporated the most severe damage from actual drop tests of the very similar MFFP. The HAC models incorporated damaged foam geometry and internal thermal conditions (replacement of opaque char with air and full thermal radiation inside the void) conservatively to account for uncertainties. Specifically, the model geometry reflected the damage to the impact limiter from a side-drop impact, an estimate of polyurethane foam decomposition after the 30-minute fire (but modeled at the beginning of the fire) and the highly unlikely "chimney effect" that can develop from combustion of foam through a split in the impact limiter skin. The analyses also included all three modes of heat transfer (conduction, convection, and radiation) and proper initial and boundary conditions.

Since the Applicant did not validate the HUFP thermal models against actual tests, the Staff carried out independent confirmatory analyses to ensure that the results obtained by the applicant were reasonable and consistent. The Staff used general purpose finite element/finite difference heat transfer computer software (MSC.PATRAN/Thermal) for these analyses. The Staff used conservative axisymmetric models to assess the applicant's results reported in the SARP. Maximum temperatures predicted by the Staff's independent analyses[3-6] were all within 10% of the results obtained by the applicant and well within the material limits stated in the SARP.

The Staff's analyses confirm that the maximum temperatures of critical components such as containment body shell and the containment seals are well below the design limits and show adequate safety margins to account for uncertainties in the material properties and loading configurations. Solar heat flux is a major contributor to the thermal loading and applied conservatively by the Applicant to ensure calculation of upper-bound temperatures. The Applicant made similarly conservative assumptions regarding gas generation and gas temperatures inside the containment body shell to ensure conservative estimates of MNOP and maximum pressures.

Increased temperatures in HUFP components will not adversely affect the subcriticality or shielding evaluations given in the SARP.

3.3.4 Thermal Evaluation under Normal Conditions of Transport

The applicant performed thermal evaluations of the HUFP with planned content loadings (DFA container and IDENT-69G containers) and NCT thermal conditions specified in 10 CFR 71.71. The evaluations included regulatory insolation and ambient conditions.

3.3.4.1 Initial Conditions

The minimum temperature of -40ºC in the package occurs only when the content decay heat load is zero in an environment at -40ºC. As noted in Section 2.3.2 of the SARP, the Cold condition of -40ºC ambient temperature will not degrade the structural performance of the HUFP. The 304L austenitic stainless steels used for the containment vessels and impact limiters do not have a ductile-to-brittle transition temperature above -40ºC. The secondary stresses from the differential thermal contraction for the Cold condition are less than those from the differential thermal expansions for the Heat condition.

3.3.4.2 Effects of Tests

The applicant performed thermal evaluations of the HUFP design under NCT thermal conditions with insolation applied to the surfaces of the package in 100°F still-air environment. Applied insolation is based on the values given in 10 CFR 71, Section 71(c) for a 12-hour time period. The applicant assumed solar absorptivity of 0.5 for the external stainless steel surfaces of the HUFP based on tested and measured values of "as received" stainless steel surfaces. This absorptivity value combined with insolation, calculated on 12-hour average applied all around the external surfaces delivers the required solar thermal loading. The applicant assumed surface emissivity of 0.30 for the containment body shell and 0.4 for the impact limiter shell based on tested and measured values of "as received" stainless steel surfaces. The applicant evaluated two content configurations, one for shipping a DFA payload and second for an IDENT-69G container payload. For each content configuration, the applicant determined (by analysis) the component temperatures for the package in the shade (steady state) as well as with insolation. The applicant used content decay heat rates of 400 watts in the DFA model and 275 watts in the IDENT-69G model. Tables 3.3-3 and 3.3-4 of the SARP present the maximum component temperatures as described in Section 3.3.1.4 of this SER. The Staff's independent calculations of the package surface temperature and the content envelope surface temperature confirm that the above results were reasonable and consistent.

Steady-state temperatures of HUFP components under NCT, including the polyurethane foam insulation, do not compromise the thermal performance of the packaging. The maximum temperatures of the insulation and the seals are well below their design limits, ensuring their structural integrity during subsequent HAC events. Increased temperatures in HUFP components will not adversely affect the subcriticality or shielding evaluations given in the SARP.

3.3.4.3 Maximum and Minimum Temperatures

Table 3.3-3 of the SARP lists the maximum and minimum component temperatures under NCT for the DFA container payload. Table 3.3-4 of the SARP lists maximum NCT temperatures for the IDENT-69G container payload. The temperatures in these tables are consistent with the Table 3.1-1 of the SARP.

3.3.4.4 Maximum Normal Operating Pressure

The MNOP within the HUFP containment body shell is due to the increased temperature of the cavity air initially at atmospheric pressure and 70°F temperature. Neither DSA nor IDENT-69G payload includes moisture that will contribute to the MNOP. As a consequence, production of hydrogen from moisture is also absent from the payload. Seal temperatures are well below their design limits, and therefore, the Staff expects no significant out-gassing from either payload. Table 3.3-5 of the SARP presents the maximum pressures for the containment body shell corresponding to NCT and NCT without insolation. The applicant calculated a maximum pressure of 3.4 psig under NCT (with insolation) and converted this value conservatively into a conservative MNOP of 10 psig. As shown in Sections 2.6.1.1 and 2.6.1.3 of the SARP, the MNOP does not produce stresses in the containment body shell that exceed the allowable stress limits. The Staff's review of the MNOP calculations confirmed that the pressure results are reasonable and conservative. Section 2.6.1.3 of the SARP assigned a design pressure of 25 psig for structural calculations under NCT.

The Staff finds that the containment body shell of the HUFP remains fully effective under the NCT as containment boundary for the payloads. The resultant deformations, of the shell, if any, will not impair the containment, shielding or criticality functions of the package. The Staff also finds that NCT thermal loadings do not impair the ability of the HUFP to withstand any HAC loading.

3.3.4.5 Maximum Thermal Stresses

Sections 2.6.1.2 and 2.6.1.3 of the SARP discuss maximum thermal stresses due to differential thermal expansion, temperature gradients or thermal cycling during NCT. Tables 3.3-3 and 3.3-

4 of the SARP provided the temperatures for the different components. The Applicant concluded that sufficient axial clearances exist and that no significant thermal stresses are induced by thermal expansion from -40 ºF to NCT with insolation. Thermal stresses are accounted in the fatigue evaluation of bolts and the containment body shell. The range of primary-plus-secondary stresses is below the allowable stress intensity.

3.3.5 Thermal Evaluation under Hypothetical Accident Conditions

The applicant evaluated HUFP thermal performance under the HAC [10 CFR 71 Section 73(c)(4)] fire event by analyses. The analyses included undamaged as well as damaged HUFP geometries to capture bounding results. However, due to the highly non-linear chemical behavior of the LAST-A-FOAM FR-3700 at high temperatures, the Applicant made no attempt to model the foam at fire temperatures from first principles. Instead, the amount of foam that will be degraded (char) during the fire was estimated from small scale fire test results provided by the foam vendor. Subsequently, the Applicant built a detailed 3-D model of the degraded impact limiter (degraded foam removed) to assess the component temperatures with full thermal radiation in the void space created at the start of the fire transient. The Staff found this modeling methodology reasonably conservative considering that intumescing of the foam into char will fill any voids created in actual fire tests.

3.3.5.1 Initial Conditions

Initial conditions for the fire analyses included the maximum heat load of 400 watts and a 100ºF ambient environment. These conditions meet the requirements of 10 CFR 71.73. Regulatory requirements permit the absence of insolation at 100ºF in determining the initial conditions for the fire event. The Applicant included insolation in the post-fire cool-down analysis. Undamaged model geometry was assumed to assess the temperatures of the containment body shell and its internals. To assess the impact of fire on the seals, the model included impact limiters damaged in a side drop followed by a puncture drop on the lid-end limiter. The Staff considers these initial conditions and models satisfactory for evaluation of HUFP thermal performance under the HAC fire.

3.3.5.2 Effects of Tests

As mentioned in Section 3.3.5.1 of this SER, the Applicant modeled an undamaged package to evaluate the thermal performance of the containment body shell, because the impact limiters do not protect it. The impact limiters protect the containment body shell seals and, therefore, this model incorporated a damaged lid-end impact limiter. Both models sustained an engulfing fire with a flame temperature of 1475ºF and an effective emissivity of 0.9 per 10 CFR 71.73(c)(4). The analyses included the influences of forced convection and thermal radiation.

The drop-damaged geometry chosen as the most unfavorable damaged condition for the thermally sensitive areas of the package was from the side-drop event combined with the puncture-drop event. The second feature included in the damaged model was to address the physical change of the impact limiter geometry by removing the crushed foam. The third feature included the foam that was expected to turn into char. The char depth was estimated at four inches around the circumference and three inches at the flat end. In addition, a postulated chimney effect was included in the model. This chimney effect resulted in removal of foam locally near the seals of the containment body shell to a radius of 7 $^{3}/_{16}$ inches, leaving only one inch of foam thickness at the location of the chimney.

3.3.5.3 Maximum Temperatures and Pressures

The Applicant's post-fire cool-down period was 10 hours long and sufficient for the various components to reach peak temperatures and nearly steady state conditions for certain critical components as shown in Figures 3.4-6 and 3.4-7 of the SARP. Table 3.4-1 of the SARP presents HAC temperatures for the various components. The table gives temperatures at the start and end of the 30-minute fire and peak temperatures reached at different times during the post-fire cool-down period. Peak temperatures of various components develop from 30 minutes to nearly three hours into the fire transient. Peak temperature for the CCC occurs at the steady state condition. Peak temperatures for all components are well below their design limits given in Table 3.4-1 of the SARP.

Maximum pressure in the containment body shell is due to the increase of the temperature of the cavity air initially at atmospheric pressure and 70°F temperature and thermal decomposition of the CCC seals. The maximum temperatures of the CCC seals are below their design limits, but calculation of a bounding body shell pressure assumed that these CCC elastomeric seals decomposed completely to ensure conservative determination of maximum pressures.
Table 3.4-2 of the SARP presents the maximum pressures for the containment body shell at various times within the HAC fire event. The Staff's review of the Applicant's calculation of pressures produced during the HAC fire event confirmed that the pressure results were reasonable and conservative. These pressures are less than 20 psig and are well below the design pressure of 25 psig as well as the maximum allowable internal pressure of 130 psig under HAC. The Applicant justifies a maximum internal pressure of 130 psig in the structural analysis discussed in Section 2.7.4.3 of the SARP.

3.3.5.4 Maximum Thermal Stresses

Section 2.7.4.2 of the SARP estimates the thermal stresses in the HUFP due to the differential thermal expansions between adjacent package components. The Applicant has concluded that axial clearances were maintained during the HAC fire event, and that no significant thermal stresses are induced due to differential thermal expansion under HAC.

The Staff finds that the containment body shell of the HUFP remains fully effective under HAC as a containment boundary for the payloads. The resultant deformations of the containment body shell, if any, will not impair the containment function of the package and will not allow water to reach the payload. Deformations of the containment body shell do not impair the shielding characteristics of the package. Hence, the HAC fire event does not adversely affect the containment, shielding, or criticality functions of the HUFP.

3.3.6 Thermal Evaluation of Maximum Accessible Surface Temperature

With a 400-watt payload decay heat rate and without insolation, the Applicant calculated the temperatures of the HUFP's accessible surfaces from surface heat flow by natural convection and thermal radiation to the environment at an ambient temperature of 100°F. The resulting maximum surface temperature is less than 185°F, supporting transport of the package by exclusive-use shipment. The Staff concurs with this analysis and conclusion. Hence, 10 CFR 71 Section 43(g) is satisfied.

3.3.7 Appendices

Appendices 3.5.1 and 3.5.2 of the SARP contain the details of the NCT and HAC thermal models as introduced briefly in the following paragraphs.

3.3.7.1 Description of Test Facilities and Equipment

The Applicant evaluated the thermal performance of the HUFP by analyses only. No tests were performed to verify the design.

3.3.7.2 Test Results

The Applicant evaluated the thermal performance of the HUFP by analyses only. Therefore, no test results are available for evaluating the thermal performance of the package.

3.3.7.3 Applicable Supporting Documents or Specifications

Chapter 3 in the SARP cites applicable supporting documents, specifications, and references at the bottom of each page as footnotes.

3.3.7.4 Details of Analyses

Appendix 3.5.1 of the SARP presents thermal models for NCT and HAC and describes them in detail. Appendix 3.5.2 of the SARP presents convection coefficient relations. Other analysis details are provided at relevant locations within Chapter 3 of the SARP. Appendix 9.19.3 of the SARP documents the Verification and Validation of the computer codes Thermal Desktop and SINDA/FLUINT.

3.4 Evaluation Findings

3.4.1 Findings

Based on review of the statements and representations in the application, the Staff concludes that the thermal design of the HUFP with the contents presented in Section 1.2.2 of the SARP has been described and evaluated adequately, and that the thermal performance of the HUFP meets the thermal requirements of 10 CFR 71.

3.4.2 Conditions of Approval

Conditions of HUFP approval for shipment of the payloads specified in SARP Tables 1.2-1 through 1.2-8 are content decay heat limits of 400 watts for the DFA containers, 275 watts for the IDENT-69G containers and 75 watts for a single IDENT-69G container.

3.5 References

[3-1] Fluor Hanford, Inc., *Hanford Unirradiated Fuel Package (HUFP) Safety Analysis Report for Packaging*, HNF-28554, Revision 2, P.O. Box 1000, Richland, WA (August 2008).

[3-2] U.S. Nuclear Regulatory Commission, 10 CFR Part 71, *Packaging and Transportation of Radioactive Materials,* 01-01-2005 Edition.

[3-3] A.A. DiSabatino, et al., *Packaging Review Guide for Reviewing Safety Analysis Reports for Packagings*, UCID-21218, Revision 3, Lawrence Livermore National Laboratory (February 2008).

[3-4] American Society of Mechanical Engineers Boiler and Pressure Vessel Code, *Section III, Rules for Construction of Nuclear Facility Components,* Division 1, Subsection NB, *Class 1 Components*, and Subsection NG, *Core Support Structures*, 2001 Edition, 2002 and 2003 Addenda.

[3-5] Nuclear Regulatory Commission*, Certificate of Compliance for Radioactive Material Packages No. 9295*, Revision 1 for Package ID No. USA/9295/B(U)F-96, January 1, 2008.

[3-6] N.K. Gupta, *Confirmatory Thermal Analysis of Hanford Unirradiated Fuel Package (HUFP)*, M-CLC-A-00327, Westinghouse Savannah River Co., Aiken, SC, (December 2007).

4. CONTAINMENT REVIEW

This section of the SER documents the review of Chapter 4, *Containment*, of the *Hanford Unirradiated Fuel Package (HUFP) Safety Analysis Report for Packaging (SARP)*[4-1] by DOE PCP Staff (the Staff). The review includes an evaluation of the SARP with respect to the requirements specified in 10 CFR 71.[4-2]

4.1 Areas of Review

The Containment review of the HUFP SARP includes the Areas of Review given in the Packaging Review Guide.[4-3]

4.2 Regulatory Requirements

The regulatory requirements of 10 CFR 71 applicable to the Containment review are those given in the Packaging Review Guide.[4-3]

4.3 Review Procedures

The following procedures were employed in the review of Chapter 4, Containment, of the SARP. These procedures correspond to the Areas of Review cited in Section 4.1 of this SER.

4.3.1 Description of the Containment Design

4.3.1.1 General Considerations for Containment Evaluation

4.3.1.1.1 Fissile Type A Packages

The HUFP is not a Type A packaging.

4.3.1.1.2 Containment Boundary Penetration

The HUFP is a Type B package designed with a "leaktight" containment boundary as defined by ANSI N14.5.[4-4] The applicant has required testing of the containment boundary (the containment structure, main O-ring seal, vent port plug seal washer, and fill-port plug seal washer) by a series of four separate tests (Section 8.1.3 of the SARP). All shall demonstrate a "leaktight" leakage rate ≤ 1 × 10-7 ref·cm3/sec, air, per Section 6.3 of ANSI N14.5.

4.3.1.1.3 Combustible-Gas Generation

The applicant has stated that combustible or reactive gas mixtures will not be generated within the HUFP under normal conditions. The only combustible material within the HUFP is the nitrile seal on the CCC. Thermal decomposition of the nitrile seals during an HAC fire event will be minor, because the seal temperature will not exceed the short-term temperature limit of the material.

4.3.1.2 Design Features

Containment Vessel – The HUFP containment vessel boundary is defined in Section 4.1.1 and Section 1.2.1.14 of the SARP. The containment does not include valves or any features intended to permit continuous venting during transportation. The only penetrations into the containment boundary are the vent port, fill port, and closure lid.

Welds – All containment vessel body welds are full penetration welds that have been radiographed in accordance with the ASME Section III, Subsection NB Code.[4-5] The HUFP drawings require examination of other safety-related welds with the liquid penetrant examination method. The applicant has required testing of all containment boundary welds to the ANSI N14.5 leak-tightness standard (Section 4.1.1.4 of the SARP).

Valves – The HUFP containment design does not incorporate valves (Section 1.2.1.7 of the SARP).

Pressure Relief Devices – The HUFP containment design does not incorporate pressure relief systems (Section 1.2.1.12 of the SARP).

Lids, Cover Plates and Similar Closure Devices – The HUFP containment vessel closure consists of a welded closure lid with a sealing surface machined to receive three O-rings. The applicant has identified the center O-ring as part of the containment boundary. The inner and outer O-rings provide a convenient means of testing the leak rate of the containment O-ring. The vent, fill and test ports are integrated into the closure lid. The closure lid secures to the containment vessel body using twenty-four (24) ¾-10 UNC socket-head cap screws. Closure bolts include hardened washers and engage threaded inserts in the body flange (Section 1.2.1.1 of the SARP). When assembled for transportation, the HUFP closure lid (with vent, fill and test ports) is completely covered by the lid-end impact limiter. The impact limiter disallows access to the lid and ports, precluding inadvertent opening of the package during normal transportation. Pressure within the containment vessel is not sufficient to force open the closure lid (Section 2.4.3 and Section 4.1.1.2 of the SARP).

Bolts and Bolt Torque – The closure lid secures to the containment body using twenty four (24) ¾-inch × 3-inch long 10 UNC socket-head cap screws (SHCSs). The SHCS material is ASTM A564, Grade 630, condition H1100 stainless steel. The applicant has specified lubrication of the screw threads prior to assembly with a low-halogen nickel-based nuclear grade lubricant. The SHCSs are tightened to 175 to 220 lb-ft torque (Section 7.1.2.3 of the SARP).

Special Containment Features for Plutonium – The applicant has required HUFP payloads in excess of 20 Ci of plutonium (i.e., driver fuel assemblies or fuel pins) to be in solid form (Section 1.2.3 of the SARP). The HUFP design does not include special features for other forms of plutonium.

Special Containment Features for Spent Fuel – The HUFP design does not include special features for containment of Spent Fuel (Section 1.2.3 of the SARP).

Containment Location, Dimensions, and Tolerances – Section 4.1.1 and Section 1.2.1.14 of the SARP describe the HUFP containment system. The description includes an illustration showing the containment boundary and dimensions. Drawings of the containment system specify dimension tolerances.

Materials of Construction – Section 1.2.1.1 of the SARP and applicable drawings describe the materials of the containment body (closure lid, closure bolts, and containment body weldment). Section 4.1.1.3 of the SARP discusses the butyl compound comprising the O-rings and seal washers. The containment body is fabricated from austenitic stainless steels that are not affected by chemical or galvanic reactions (Section 2.2.2 of the SARP).

Maximum and Minimum Allowable Temperature of Components – Section 3.1.3 of the SARP discusses the maximum HUFP temperatures under NCT and HAC. The applicant's testing and analysis demonstrate that under both NCT and HAC conditions, all packaging components will remain within their respective maximum temperature limits. Minimum material temperatures achieved within operational limits also comply with the material specifications.

Maximum Normal Operating Pressure and Maximum Pressure in the Containment System under HAC – Section 3.1.4 of the SARP summarizes the maximum containment pressures under NCT and HAC conditions. The applicant has predicted the maximum HUFP containment system pressure under NCT (with specific conservative assumptions) to be 3.4 psig. This value is less than the maximum normal operating pressure (MNOP) of 10 psig assumed in the SARP for structural calculations. The applicant has estimated the maximum peak pressure generated within the package cavity under HAC conditions to be 18.5 psig, which is below the 25 psig design pressure.

4.3.1.3 Codes and Standards

Chapters 1, 2, and 3 of the SARP identify the ASME BP&V Section III, Subsection NB, Division 1 as the code governing the design of the containment structure. Material specifications are suitable for design and fabrication and are within the temperature limits for the materials.

4.3.1.4 Special Requirements for Plutonium

The HUFP is a single-containment system designed to contain payloads in excess of 20 Ci of plutonium in solid form. The requirements of 10 CFR 71.63 are satisfied (Section 1.2.3 of the SARP).

4.3.1.5 Special Requirements for Spent Fuel

Spent Fuel is not among the contents evaluated for containment within the HUFP (Section 1.2.2 of the SARP).

4.3.2 Containment under Normal Conditions of Transport

4.3.2.1 Containment Design Criteria

The HUFP containment system is designed to meet the ANSI N14.5 definition of leaktight ($\leq 1 \times 10^{-7}$ ref·cm3/sec, air).

4.3.2.2 Demonstration of Compliance with Containment Design Criterion

The Applicant's primary proof of leak-tightness of the HUFP design under NCT is via analytical methods. The criteria of Regulatory Guide 7.6, *Design Criteria for the Structural analysis of Shipping Cask Containment Vessels*,[4-6] were demonstrated as acceptable for all NCT analytic evaluations (Section 2.6 of the SARP).

The HUFP design utilizes the same containment body and impact limiters as those of the certified Mixed-Oxide Fresh Fuel Package (MFFP).[4-7]

4.3.3 Containment under Hypothetical Accident Conditions

4.3.3.1 Containment Design Criterion

The HUFP containment system is designed to meet the "leaktight" definition of ANSI N14.5 (Section 4.3.3 of the SARP).

4.3.3.2 Demonstration of Compliance with Containment Design Criterion

Section 2.7, Section 3.4 and Appendix 2.12.3 of the SARP document the results of HAC structural and thermal analyses and the results of the full-scale structural testing. The applicant demonstrated HUFP compliance with the requirements of 10 CFR 71.73 by a combination of analytical modeling and comparison with MFFP full-scale testing. The HUFP design incorporates the same containment body and impact limiters as those of the MFFP. Part of the MFFP certification effort included full-scale testing of the containment boundary and impact limiter designs under a series of HAC free- and puncture-drop events. The MFFP results are directly applicable to the HUFP, because the containment boundary and impact limiters are identical. The differences between the two packaging designs are internal components. Detailed dynamic finite element analysis of the HUFP supplemented the MFFP drop tests. The full-scale tests in combination with the corroborating analytical evaluations demonstrate leak-tightness (as defined in ANSI N14.5) of the HUFP's containment system (Section 1.1 and Section 2.7 of the SARP).

4.3.4 Leakage Rate Tests for Type B Packages

Section 4.4 of the SARP requires demonstration of the containment boundary as "leaktight" per ANSI N14.5 as part of fabrication acceptance, periodic testing, and maintenance testing. The acceptable leakage rate for the pre-shipment leakage rate test is $\leq 1 \times 10^{-3}$ ref·cm^3/sec, air (Section 4.4 of the SARP).

4.3.5 Appendices

Chapter 4 of the SARP does not include appendices. Further, reference documents cited in Chapter 4 of the SARP are given as footnotes listed at the bottoms of appropriate pages.

4.4 Evaluation Findings

Based on a review of the statements and representations given in the SARP, the staff concludes that the SARP describes and evaluates the containment design adequately and that the HUFP design meets the containment requirements of 10 CFR 71.

4.4.1 Conditions of Approval

Containment-related conditions of approval are not needed for the approval of this application.

4.5 References

[4-1] Fluor Hanford, Inc., *Hanford Unirradiated Fuel Package (HUFP) Safety Analysis Report for Packaging*, HNF-28554, Revision 2, P.O. Box 1000, Richland, WA (August 2008).

[4-2] U.S. Nuclear Regulatory Commission, 10 CFR Part 71, *Packaging and Transportation of Radioactive Materials,* 01-01-2005 Edition.

[4-3] A.A. DiSabatino, et al., *Packaging Review Guide for Reviewing Safety Analysis Reports for Packagings*, UCID-21218, Revision 3, Lawrence Livermore National Laboratory (February 2008).

[4-4] American National Standards Institute, Inc., American National Standard for Radioactive Materials - Leakage Tests on Packages for Shipment, ANSI N14.5-1997 New York (1997).

[4-5] American Society of Mechanical Engineers Boiler and Pressure Vessel Code, *Section III, Rules for Construction of Nuclear Power Plant Components, Division 1, Subsection NB, Class 1 Components*, 2001 Edition, 2002 and 2003 Addenda. (More recent editions/addenda may be used for fabrication.)

[4-6] U.S. Nuclear Regulatory Commission, Regulatory Guide 7.6, *Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels*, Revision 1, March 1978.

[4-7] U.S. Nuclear Regulatory Commission*, Certificate of Compliance for Radioactive Material Packages No. 9295*, Revision 1 for Package ID No. USA/9295/B(U)F-96, January 1, 2008.

5. SHIELDING REVIEW

This section of the SER documents the review of Chapter 5, Shielding, in the *Hanford Unirradiated Fuel Package (HUFP) Safety Analysis Report for Packaging (SARP)*[5-1] by DOE PCP Staff (the Staff). The review includes an evaluation of the SARP with respect to the requirements specified in 10 CFR 71.[5-2]

5.1 Areas of Review

The Shielding review includes the Areas of Review given in the Packaging Review Guide.[5-3]

5.2 Regulatory Requirements

Regulatory requirements of 10 CFR 71 applicable to the Shielding review are those given in the Packaging Review Guide.[5-3]

5.3 Review Procedures

Chapter 5 of the HUFP SARP includes the information needed for a shielding evaluation: design features, modeling description, packaging material specifications (densities and compositions), radiation source material compositions, and determination of radiation source spectra and strengths. The Staff reviewed the dose rate analysis (shielding evaluation) given in the HUFP SARP for completeness and consistency with regulations.

5.3.1 Description of Shielding Design

5.3.1.1 Design Features

The HUFP and its internals do not contain dedicated shielding materials. However, the materials of construction (i.e., steel) for the core component container (CCC), CCC-Adapter, and HUFP shell provide gamma shielding. In the radial direction, each CCC tube provides ⅜ inch of shielding, the CCC-Adapter provides ¼ inch of shielding and the HUFP shell provides $^{9}/_{16}$ inch of shielding. In the bottom axial direction, the HUFP provides 1½ inches of shielding, and in the top axial direction, the HUFP lid provides 1⅜ inches of shielding. The internal components and impact limiters also provide axial shielding, although dose rates in the axial direction are negligible.

The design features considered in the shielding evaluation are consistent with the design features presented in the General Information chapter of the SARP.

5.3.1.2 Codes and Standards

Codes and Standards related to construction and materials of the HUFP are not addressed directly in Chapter 5. However, construction and choice of materials for the HUFP are affected by the codes and standards called out in other chapters (i.e., General Information, Structural, Thermal). The material compositions the Applicant used in the shielding analysis are representative of the actual materials specified for the HUFP in those chapters.

The flux-to-dose-rate conversion factors are listed in Table 5.4-1 of the SARP and are consistent with ANSI/ANS-6.1.1-1977.[5-4]

5.3.1.3 Summary Table of Maximum Radiation Levels

Table 5.3-1 of this SER summarizes the Applicant's calculated maximum external dose rates for the HUFP under both Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAC) as reported in the SARP. These are the largest external dose rates and associated with a payload of six IDENT-69G containers. The dose rates in this table are located at the side of the package. Dose rates at the ends of the package are negligible (i.e., ~1 mrem/hr on the package end surfaces, compared to 291.5 mrem/hr on the package side surface) and thus, are well bounded by the package-side dose rates. The dose rate limits given in Table 5.3-1 are for exclusive use transportation as allowed in 10 CFR 71.47. The HUFP with the proposed payload may be shipped exclusive use only.

These dose rates are consistent with confirmatory dose rate calculations.[5-5]

Table 5.3-1 Summary Table of Maximum External Radiation Dose Rates

Radiation	**NCT**			**HAC**
	Package Side Surface (mrem/hr)	Vehicle Bottom Surface (mrem/hr)	2 m from Vehicle Side Surface (mrem/hr)	1 m from Package Side Surface (mrem/hr)
Gamma	6.9	2.2	0.1	0.7
Neutron	284.6	77.9	4.5	25.7
Total	291.5	80.1	4.6	26.4
Limit	1000	200	10	1000

5.3.2 Radiation Source

The radiation source for the HUFP consists of either seven Driver Fuel Assemblies (DFAs), each holding 217 fuel pins, or six IDENT-69G containers filled with loose fuel pins. The fuel pins are primarily mixed-oxide (MOX) fuel, consisting of a mixture of plutonium and uranium oxides. The plutonium isotopes, with a higher specific activity than the uranium isotopes, result in most of the measurable dose rate. The fuel is unirradiated; therefore, fission product decay is not a concern. The dose rate outside the HUFP is due primarily to neutrons from spontaneous fission in plutonium or (α,n) reactions involving plutonium α particles. Most of the emitted gammas are low-energy and essentially absorbed by the steel packaging.

The Applicant assumed total decay times of 36 and 39 years for the DFA and the IDENT-69G, respectively. ORIGEN-S[5-6], a module of the SCALE[5-7] system, was used to calculate the source spectra and strength, based on the fuel mass in a fuel container, 38,774.8 g per DFA and 56,499.4 g per IDENT-69G.

5.3.2.1 Gamma Source

Table 5.3-2 of this SER lists the calculated gamma spectra and source strengths as reported in the SARP. These spectra and source strengths are consistent with the spectra and source strengths derived in the confirmatory dose-rate calculations.[5-5]

Table 5.3-2 Applicant's Gamma Sources

Lower Bin Boundary (MeV)	**Upper Bin Boundary** (MeV)	**DFA Gamma Source** (γ/s)	**DFA Gamma Source** (MeV/s)	**IDENT-69G Gamma Source** (γ/s)	**IDENT-69G Gamma Source** (MeV/s)
1.00E-02	2.00E-02	1.281E+13	1.921E+11	1.276E+13	1.914E+11
2.00E-02	3.00E-02	1.951E+12	4.877E+10	1.890E+12	4.725E+10
3.00E-02	6.00E-02	6.627E+12	2.982E+11	6.342E+12	2.854E+11
6.00E-02	1.00E-01	3.701E+12	2.961E+11	3.540E+12	2.832E+11
1.00E-01	2.00E-01	9.723E+09	1.459E+09	1.033E+10	1.550E+09
2.00E-01	4.00E-01	2.412E+09	7.236E+08	2.832E+09	8.496E+08
4.00E-01	6.00E-01	3.330E+08	1.665E+08	4.548E+08	2.274E+08
6.00E-01	7.00E-01	1.587E+08	1.031E+08	1.580E+08	1.027E+08
7.00E-01	8.00E-01	7.726E+07	5.794E+07	7.650E+07	5.738E+07
8.00E-01	1.00E+00	4.803E+06	4.322E+06	5.471E+06	4.924E+06
1.00E+00	1.50E+00	2.686E+06	3.357E+06	3.577E+06	4.472E+06
1.50E+00	2.00E+00	9.181E+05	1.607E+06	1.235E+06	2.162E+06
2.00E+00	3.00E+00	5.488E+05	1.372E+06	7.304E+05	1.826E+06
3.00E+00	4.00E+00	1.819E+05	6.365E+05	2.426E+05	8.492E+05
4.00E+00	5.00E+00	6.040E+04	2.718E+05	8.081E+04	3.636E+05
5.00E+00	6.00E+00	2.011E+04	1.106E+05	2.696E+04	1.483E+05
6.00E+00	7.00E+00	6.710E+03	4.361E+04	9.011E+03	5.857E+04
7.00E+00	8.00E+00	2.243E+03	1.682E+04	3.016E+03	2.262E+04
8.00E+00	1.00E+01	9.747E+02	8.773E+03	1.312E+03	1.181E+04
1.00E+01	1.40E+01	4.594E+01	5.513E+02	6.191E+01	7.429E+02
Subtotal (1 DFA or 1 IDENT-69G)		2.510E+13	8.377E+11	2.455E+13	8.100E+11
Total (7 DFAs or 6 IDENT-69Gs)		1.757E+14	5.864E+12	1.473E+14	4.860E+12

5.3.2.2 Neutron Source

Approximately half the Applicant's calculated neutron dose rate is due to spontaneous fission of Pu-240. The remaining neutron dose rate is primarily due to (α,n) reactions of α particles from Pu-238, Pu-239, Pu-240, and Am-241 (a daughter product of Pu-241, which has a half-life of 14.35 years). The neutron sources as reported in the SARP are listed in Table 5.3-4 of this SER. The ORIGEN-S calculations as described in Section 5.2.2 of the SARP accounted for the effect of neutron multiplication. These spectra and source strengths are consistent with the spectra and source strengths derived in the confirmatory calculation. Differences exist between the neutron source strengths reported in Table 5.3-3 and the neutron source strengths in the confirmatory calculations because the Applicant's neutron multiplication effect was estimated based on neutron multiplication observed in Chapter 6, *Criticality*, while the neutron multiplication in the confirmatory calculations was handled explicitly in the MCNP neutron dose rate calculations.

Table 5.3-3 Applicant's Neutron Sources

Lower Bin Boundary (MeV)	Upper Bin Boundary (MeV)	DFA Neutron Source (n/s)	IDENT-69G Neutron Source (n/s)
1.00E-11	1.00E-01	2.279E+04	2.914E+04
1.00E-01	4.00E-01	1.384E+05	1.786E+05
4.00E-01	9.00E-01	2.884E+05	3.719E+05
9.00E-01	1.40E+00	3.094E+05	3.943E+05
1.40E+00	1.85E+00	3.170E+05	3.909E+05
1.85E+00	3.00E+00	9.515E+05	1.118E+06
3.00E+00	6.43E+00	5.301E+05	6.256E+05
6.43E+00	8.00E+00	1.227E+04	1.647E+04
8.00E+00	2.00E+01	4.145E+03	5.541E+03
Subtotal (1 DFA or 1 IDENT-69G)		2.574E+06	3.130E+06
Total (7 DFAs or 6 IDENT-69Gs)		1.802E+07	1.878E+07
Total Including Subcritical Neutron Multiplication		3.463E+07	5.747E+07

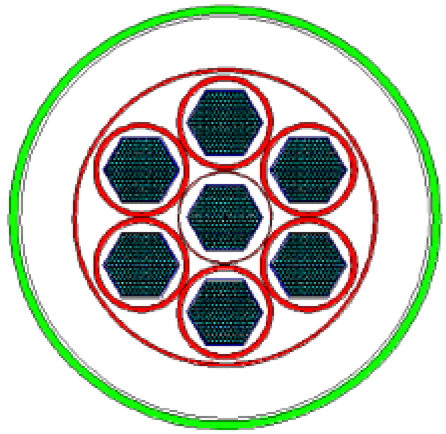
5.3.3 Shielding Model

The Applicant's shielding models are consistent with the HUFP description in the General Information Chapter of the HUFP SARP.

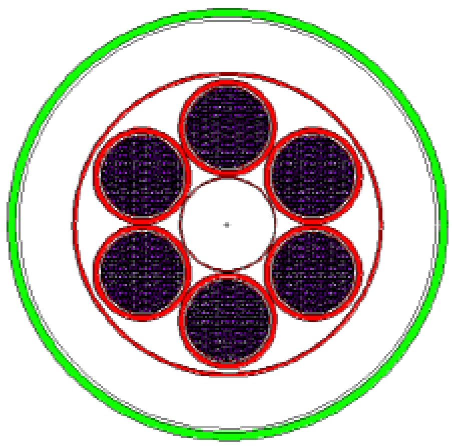
5.3.3.1 Configuration of Source and Shielding

The Applicant used MCNP[5-8] to perform detailed 3-D shielding calculations. The shielding models are based upon the configurations developed for the criticality analysis presented in Chapter 6 of the SARP. Figure 5.3-1 of this SER shows the cross sections of the DFA and IDENT-69G models. The source in each model is evenly distributed throughout the active length of the fuel rods. No water is modeled in the system as it would moderate the neutron spectrum and reduce the neutron dose rate. Because the regulatory drop tests and the structural analyses given in Chapter 2 demonstrated that possible damage to the HUFP was minimal, the Applicant used only NCT models in the calculations.

The SARP models contained all relevant dose rate locations for both NCT and HAC. The Applicant's dose rate locations conservatively represent the dose rate locations for a HUFP on a transport vehicle. Circumferential surface dose rate (F2) tallies are specified for the package surface, the transport vehicle surface, and 2 m from the transport vehicle surface. The tallies are centered on the axial center of the fuel in the package (fuel length = 36 inches) and are modeled as 12 inches wide (See SER Figure 5.3-2).



DFA Model



IDENT-69G Model

Figure 5.3-1 Applicant's DFA and IDENT-69G Models – Cross Section View

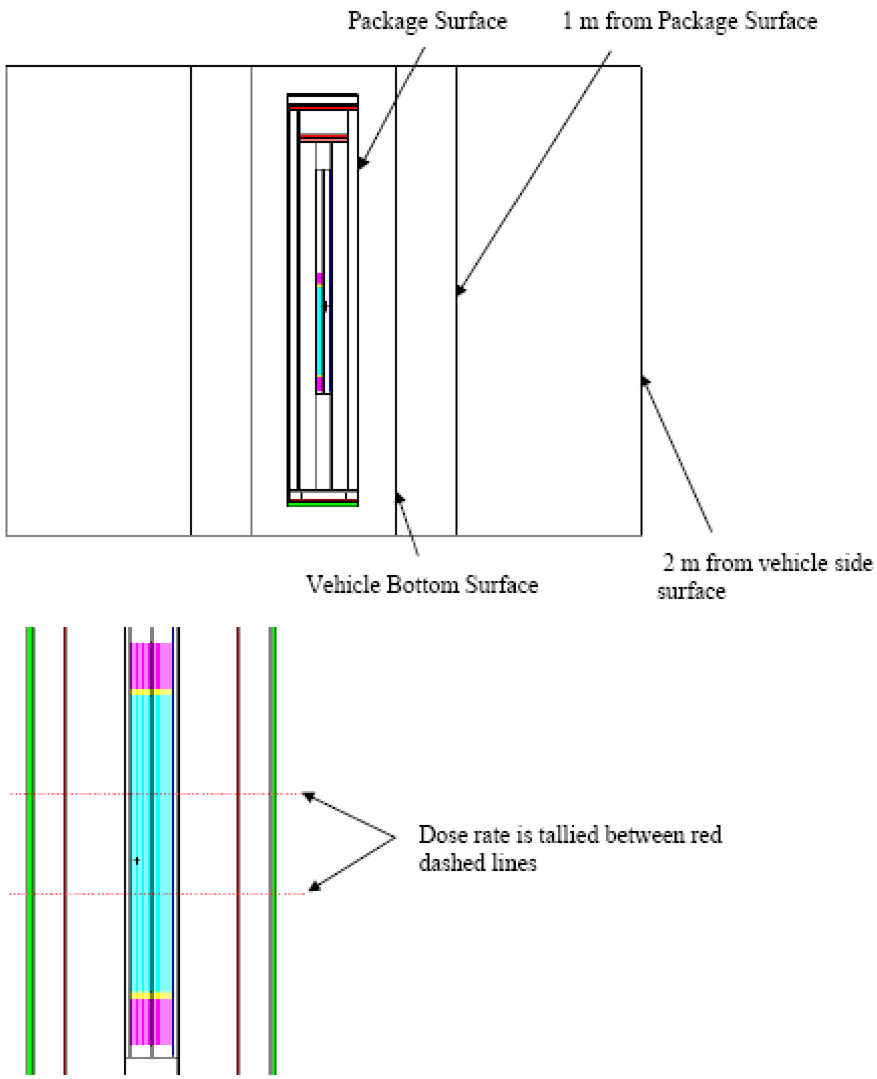


Figure 5.3-2 Applicant's Tally Locations - DFA Model

5.3.3.2 Material Properties

The material properties (material densities and compositions) were the standard compositions for the HUFP materials, and used also in the criticality analyses. Tables 5.3-1 through 5-3-5 of the SARP provide the specific compositions used in the dose rate analyses.

5.3.4 Shielding Evaluation

The Applicant's shielding evaluation considered both the DFA and the IDENT-69G containers.

5.3.4.1 Methods

The Applicant computed dose rates using a detailed 3-D MCNP model. MCNP is a standard Monte Carlo particle transport program that has been used extensively in the analysis of many transportation packages. Subcritical neutron multiplication was accounted for manually using the conservative technique described in Section 5.2.2 of the SARP.

Because there is no hydrogen inside the fuel payload, and no neutron shield around the packaging, the secondary gamma dose rate is a negligible fraction of the total dose rate and not calculated explicitly.

The Applicant modeled the source explicitly within the pellet material of each fuel pin, distributed evenly along the 36-inch active fuel length.

Dose rates are computed from surface tallies centered axially along the active fuel length. MCNP computes the fluxes on various surfaces around the model, and then converts these fluxes to dose rates using conversion factors (see Section 5.3.4.3 of this SER, *Flux-to-Dose Rate Conversion*).

5.3.4.2 Input and Output Data

Section 5.5.2.2 of the SARP presents an example MCNP input file for the DFA neutron model. The source is consistent with the source terms provided in Tables 5.3-3 and 5.3-4. The input files are consistent with the model description in Section 5.3.3.

The SARP does not list output files. However, the calculated dose rates in the confirmatory calculations are consistent with the reported maximum dose rates in SER Table 5.3-1.

The Applicant's neutron model calculations converged rapidly in the radial direction, as the dose rates are highest at the side of the package. The gamma dose rates converged more slowly because many of the gammas are shielded by the steel packaging materials. The total dose rates at the side of the cask have 1-sigma statistical uncertainties less than 1%, which is well converged.

5.3.4.3 Flux-to-Dose-Rate Conversion

The SARP properly converts the calculated fluxes to dose rates. Per the recommendation of the United States Nuclear Regulatory Commission (NRC), MCNP calculations utilize ANSI/ANS-6.1.1-1977 flux-to-dose rate conversion factors. Table 5.4-1 of the SARP presents these factors for both neutron and gamma radiation.

5.3.4.4 External Radiation Levels

Table 5.3-1 of this SER presents a summary of the Applicant's computed maximum dose rates for HUFP payloads. The as-computed dose rates exceed the regulatory limits for non-exclusive use transport (10 CFR 71.47(a)), but all exclusive-use dose rate limits are met. The IDENT-69G payload delivers considerably higher dose rates than the DFA payload. This behavior is expected, because six IDENT-69G containers have a much larger source than seven DFAs when subcritical neutron multiplication is considered.

Neutrons dominate the dose rate at all external dose rate locations relevant to transportation. The gamma dose rate comprises approximately 5% of the total dose rate external to the package. However, the gamma source is not insignificant, as the gamma source is well shielded by the CCC, CCC-Adapter, and HUFP shell. These steel components offer little shielding for neutrons.

Although not shown in SER Table 5.3-1, the total dose rates at the ends of the package body (i.e., bottom and lid) are reported in the SARP to be negligible (~1 mrem/hr), even though the impact limiters have been ignored and would further reduce the dose rates by increasing the distance from the source (and adding shielding). Likewise, the dose rate to the vehicle driver, who would be located approximately five m from the end of the HUFP, would also be negligible (i.e., much less than the limit of 2 mrem/hr).

The Applicant's dose rate maxima presented in SER Table 5.3-1 are highly conservative because of conservative treatment of subcritical neutron multiplication, which can increase the neutron dose rate by as much as 50%.

The shipper must measure dose rates from the loaded HUFP prior to transportation and these measurements will likely be significantly lower than the calculated values. The SARP reports that a limited quantity of measured dose rate information is available for bare DFAs and a bare loaded IDENT-69G container. These data indicate that the MCNP calculations provide reasonable predictions of dose rates.

5.3.5 Appendices

Sections 5.5.1 and 5.5.2 of the SARP are appendices in which the methodology (model and sources) are benchmarked against (compared with) measurements. The SARP reports that a limited quantity of measured dose rate information is available for bare DFAs and a bare loaded IDENT-69G container. Section 5.5.1 of the SARP also documents benchmarking of these data against the ORIGEN-S/MCNP methodology. This section of the SARP concludes that MCNP accurately predicts the measured neutron dose rate, although MCNP appears to over predict the measured gamma dose rate conservatively by a factor of 3 to 5.

5.4 Evaluation Findings

5.4.1 Findings

- The Staff review has demonstrated that the review items listed in Sections 5.3.1 through 5.3.5 of the PRG have been addressed adequately.
- Confirmatory shielding (i.e., dose rate) calculations[5-5] verified that dose rates from the HUFP with the DFA and the IDENT-69G payloads exceed the non-exclusive use limits but not the exclusive use limits of 10 CFR 71, in agreement with the Applicant's analysis.
- As stated in the SARP, the HUFP is restricted to "exclusive use" and must be shipped one package per transport vehicle.
- As stated in the SARP, HUFP radiation dose rates must be measured prior to shipment.
- Based on review of the statements and representations in the SARP, the Staff concludes that the shielding design has been described adequately and evaluated conservatively and that the package meets the external radiation requirements of 10 CFR 71.

5.4.2 Conditions of Approval

Section 5 of the Certificate of Compliance must contain the restriction that the HUFP be constructed as specified on the engineering drawings given in the SARP. The CoC must also contain the following restrictions.

- HUFP contents are restricted to the unirradiated fuel defined by Tables 1.2-1 through 1.2-8 of the SARP. The HUFP payload may include up to
  - seven Driver Fuel Assemblies (DFAs),
  - six low-reactivity IDENT-69G containers, or
  - one high-reactivity IDENT-69G container plus three low-reactivity IDENT-69G containers.
- The IDENT-69G containers are restricted to 250 fuel pins in a low-reactivity IDENT-69G container and 150 fuel pins in a high-reactivity IDENT-69G container. Chapter 6 of the SARP specifies allowable fuel pin combinations for the low-reactivity IDENT-69G containers and the high-reactivity IDENT-69G containers.
- The HUFP is restricted to exclusive use transport and one package per transport vehicle.
- As stated in the SARP, the shipper must measure radiation dose rates from the loaded HUFP prior to shipment.

5.5 References

[5-1] Fluor Hanford, Inc., *Hanford Unirradiated Fuel Package (HUFP) Safety Analysis Report for Packaging*, HNF-28554, Revision 2, P.O. Box 1000, Richland, WA (August 2008).

[5-2] U.S. Nuclear Regulatory Commission, 10 CFR Part 71, *Packaging and Transportation of Radioactive Materials,* 01-01-2005 Edition.

[5-3] A.A. DiSabatino, et al., *Packaging Review Guide for Reviewing Safety Analysis Reports for Packagings*, UCID-21218, Revision 3, Lawrence Livermore National Laboratory (February 2008).

[5-4] ANS-6.1.1 Working Group, *American National Standard Neutron and Gamma-Ray Flux-to-Dose-Rate Factors*, ANSI/ANS-6.1.1-1977, American Nuclear Society, La Grange Park, IL, (1977)

[5-5] A.H. Bridges and R.L. Reed, *Shielding Analysis of the HUFP with DFA and IDENT-69G (U)*, N-CLC-A-00069, Revision 0, Washington Safety Management Solutions LLC (December 2007).

[5-6] I.C. Gauld, O.W. Hermann, and R.M. Westfall *ORIGEN-S: SCALE System Module to Calculate Fuel Depletion, Actinide Transmutation, Fission Product Buildup and Decay, and Associated Radiation Source Terms,* ORNL/TM-2005/39, Version 5, Vol. II, Book 1, Section F7 (April 2005).

[5-7] Oak Ridge National Laboratory, *SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation*, ORNL/TM-2005/39, Version 5, Vols. I-III (April 2005).

[5-8] X-5 Monte Carlo Team, *MCNP – A General Monte Carlo N-Particle Transport Code, Version 5; Volume II: User's Guide*, LACP-03-0245, Los Alamos National Laboratory (April 2003).

6. CRITICALITY REVIEW

This section of the SER documents the review of Chapter 6, *Criticality*, of the *Hanford Unirradiated Fuel Package (HUFP) Safety Analysis Report for Packaging (SARP)*[6-1] by DOE PCP Staff (the Staff). The review verifies compliance with criticality safety requirements. The review includes an evaluation of the SARP with respect to the requirements specified in 10 CFR 71.[6-2]

6.1 Areas of Review

The Criticality review includes the Areas of Review given in the Packaging Review Guide.[6-3]

6.2 Regulatory Requirements

The regulatory requirements of 10 CFR 71 applicable to the Criticality review and are those cited in the Package Review Guide.[6-3]

6.3 Review Procedures

Chapter 6 of the HUFP SARP includes the information essential for a criticality evaluation including package description (detailed in the Packaging General Arrangement Drawings given in Chapter 1), identification of packaging materials and their densities and compositions, and the fissile/fissionable material forms, masses, and isotopic compositions. The Staff reviewed the SARP criticality information for completeness and compliance with regulatory requirements. Of particular note is that the HUFP undergoes minimal geometric distortion under the various accident conditions. Hence, the primary influence of the hypothetical accident conditions (HAC) in criticality behavior is the assumed presence of water within various parts of the HUFP and its payload as a moderator at optimized densities.

6.3.1 Description of Criticality Design

6.3.1.1 Design Features

Section 1.2 and Appendix 1.3.2 of the HUFP SARP provide detailed descriptions of the HUFP design. As noted in the SARP, the primary design features important for criticality safety are the geometrical controls provided by the packaging, the core component container (CCC), the CCC-Adapter and the IDENT-69G container. No neutron absorbing (poison) materials are incorporated into the packaging design. The HUFP contains up to seven Driver Fuel Assemblies (DFA) or up to six IDENT-69G containers of loose fuel pins.

Descriptions of the HUFP design features and the models used in the criticality calculations are consistent with the drawings and the detailed package description in given in Section 1.2 of the SARP. The HUFP conforms to the general standards for packages as prescribed by 10 CFR 71 [e.g., §71.31(a), §71.31(a)(2), §71.31(c), §71.33, §71.35(a)].

The HUFP SARP has assigned a proper Criticality Safety Index (CSI) of 100 to the HUFP with the proposed payloads (i.e., only one HUFP may be shipped on a transport vehicle).

6.3.1.2 Codes and Standards

Codes and standards related to construction and materials of the HUFP are not addressed directly in Chapter 6. However, construction and choice of materials for the HUFP are affected by the codes and standards called out in other chapters (i.e., General Information, Structural, Thermal). The material compositions the Applicant used in the criticality analysis are representative of the actual materials specified for the HUFP in those chapters.

6.3.1.3 Summary Table of Criticality Evaluation

Table 6.3-1 of this SER is a compilation of the calculational results (from Tables 6.1.1 and 6.1.2 of the SARP) for the HUFP with the DFA payload and with the IDENT-69G payload. The analysis summarized in Table 6.3-1 is consistent with the derived Criticality Safety Index (CSI) of 100 (A single HUFP per transport vehicle). Confirmatory calculations[6-4] are consistent with the Applicant's calculational results showing that the HUFP with either proposed payload is subcritical under single package conditions (10 CFR §71.55(b), (d), and (e)), within an array of packages under NCT [§71.59(a)(1)] and as a single damaged package under HAC [§71.59(a)(2)]. For each configuration modeled, the maximum value of the effective multiplication factor (k_{eff}) is less than the Upper Safety Limit value (USL) of the effective multiplication factor (k_{eff}).

Table 6.3-1 Summary of the Applicant's Criticality Analysis Results

Normal Conditions of Transport (NCT)			
Case	k_{eff}	σ	k_s
DFA, Single Unit Maximum	0.47928	0.00024	0.47976
DFA, Infinite Array Maximum	0.85755	0.00068	0.85891
IDENT-69G Single Unit Maximum	0.67152	0.00082	0.67316
IDENT-69G, Finite Array (3 packages) Maximum	0.74650	0.00080	0.74810
Hypothetical Accident Conditions (HAC)			
DFA, Single Unit Maximum	0.86857	0.00051	0.86959
DFA, Array Maximum (same as single unit)	0.86857	0.00051	0.86959
IDENT-69G, Single Unit Maximum	0.91116	0.00097	0.91310
IDENT-69G, Array Maximum (same as single unit)	0.91116	0.00097	0.91310
USL	0.9304		

6.3.2 Fissile Material and Other Contents

The fissile material contents evaluated for shipment in the HUFP are Driver Fuel Assemblies (DFAs), each of which contains 217 mixed-oxide fuel pins in a hexagonal lattice in a hexagonal SS316 duct and IDENT-69G containers of loose fuel pins (mixed-oxide fuel pins and uranium oxide fuel pins). The fuel pin's U-235 enrichment and plutonium content vary over a wide range. Chapter 1 and Chapter 6 of the SARP specify the fuel pin characteristics in detail. Depending on the specific combination of fuel pins within an IDENT-69G container, the container is identified as a low-reactivity IDENT-69G container (containing up to 250 low-reactivity fuel pins) or a high-reactivity IDENT-69G container (containing up to 150 high-reactivity fuel pins). The HUFP may accommodate up to seven DFAs, six low-reactivity IDENT-69G containers or one high-reactivity IDENT-69G container and three low-reactivity IDENT-69G containers.

6.3.3 General Considerations for Criticality Evaluations

6.3.3.1 Model Configuration

The Applicant's MCNP models used for criticality analyses represent accurately all major design features of the package and contents. The model simplifies some features on the axial ends (e.g., DFA inlet nozzle) of the package, because they have negligible effect on the reactivity of the loaded HUFP.

The Applicant modeled IDENT-69G containers with the fuel pins distributed radially and uniformly within the container rather than grouped together on one side of the container as in the actual configuration. In the actual configuration, aluminum dunnage rods fill the empty space within the container. The modeled configuration provides a higher H/fissile ratio, conservatively maximizing reactivity when moderator is present within the IDENT-69G container.

The IDENT-69G loading in the CCC was considered as either of two general loading configurations.

- Low-Reactivity CCC contains up to six low-reactivity IDENT-69G containers. A high-reactivity IDENT-69G in the CCC is not allowed.
- High-Reactivity CCC contains up to three low-reactivity IDENT-69G containers and one high-reactivity IDENT-69G container. More than one high-reactivity IDENT-69G within a CCC is not allowed.

The low-reactivity CCC configuration is the most reactive, because it contains the most fissile material.

6.3.3.2 Material Properties

The fissile materials modeled in the criticality analyses include payload material compositions and forms specified in Chapter 1 (based on facility specifications for the payload materials). Section 6.2 of the SARP provides materials density and composition details. Where the composition of the fissile material could vary (e.g., from radioactive decay of Pu-241), the analyses used the most reactive composition over the life of the fissile material.

The Applicant's construction materials for the HUFP, the CCC, the CCC-adaptor, the DFA duct, and the IDENT-69G container are standard materials, primarily various forms of stainless steel. Section 6.3.2 of the SARP provides material composition details. Other materials modeled in the

NCT cases were several densities of water representing moderator and pure aluminum representing the dunnage material.

6.3.3.3 Demonstration of Maximum Reactivity

The HUFP SARP examined multiple conditions for each payload configuration to determine the optimum moderator combination for the HAC cases, including variation of moderator density throughout the various regions of the HUFP, the CCC and the fuel regions (DFA or IDENT-69Gs). Modeled variations in moderator within the CCC (e.g., different regions of the CCC with water at different densities) are not all physically possible, but bound possible configurations relative to system reactivity. Table 6.3-1 of this SER summarizes the Applicant's calculations of k_{eff} for the various configurations, demonstrating that a single HUFP with any of the allowed payloads will remain subcritical under all regulatory conditions. These calculational results are consistent with the confirmatory calculations.[5-4]

6.3.3.4 Computer Codes and Cross-Section Libraries

The criticality studies reported in the SARP used the MCNP 5 computer code[6-5] with the continuous energy ENDF/B-VI cross-section library. For elements (e.g., iron, chromium, and nickel) not available in the continuous energy ENDF/B-VI cross-section library, the analyses used the older continuous energy ENDF/B-V cross-section library. MCNP 5 and the associated cross-section libraries are appropriate for the criticality calculations. As stated in Chapter 6 of the SARP, the USL of 0.9304 was determined on the basis of a benchmark analysis and incorporated the combined effects of code computational bias, uncertainty in the bias based on both benchmark-model and computational uncertainties and an administrative margin. The results of the benchmark analyses showed that the Applicant's USL is adequate to ensure subcriticality of the HUFP.

The SARP criticality study used a range of neutron histories (375,000 – 2,500,000) to obtain k_{eff} values with statistical uncertainties ranging from 0.00024 to 0.00097. The number of neutron histories is adequate to assure that each fissile system analyzed was sampled in a statistically acceptable manner.

The SARP includes no output listings, but the Applicant provided these separately for review. The confirmatory calculations[6-4] verified the Applicant's results. Appendix 6.9 of the SARP provides examples of MCNP input files including proper entry of model input parameters, material densities and cross sections.

6.3.4 Single Package Evaluation

The Staff concludes that the HUFP conforms to the criticality requirements as prescribed by 10 CFR 71, i.e., §71.43(f), §71.51(a), §71.55(b), §71.55(d), §71.55(e).

6.3.4.1 Configuration

The SARP determined that the maximum reactivity of a single HUFP with optimized geometry and moderation conditions as required in §71.55(b) occurs from a payload of IDENT-69G containers of loose fuel pins. This corresponded to a loaded HUFP under HAC, but with optimized internal water flooding in which water densities varied in various inner components to maximize the interaction between IDENT-69G containers.

6.3.4.2 Results

The HUFP design under NCT meets the additional requirements from 10 CFR 71.55(d)(2) through §71.55(d)(4). The Applicant's criticality analysis results for the most reactive single-package case are presented in SER Table 6.3-1.

The Staff's analyses confirm the validity of the Applicant's criticality analyses of the HUFP.

6.3.5 Evaluation of Undamaged-Package Arrays (Normal Conditions of Transport)

The SARP states that HUFP is designed, constructed, and prepared for shipment so that there will be no significant reduction in the criticality safety of the package during NCT. The HUFP meets the NCT criticality requirements for arrays of fissile material packages given in 10 CFR 71.59(a)(1) and §71.59(a)(3).

6.3.5.1 Configuration

The SARP documents evaluation of NCT configurations for the HUFP payloads of either DFAs or IDENT-69G containers of loose fuel pins. For the NCT array configuration, the package interior is dry (void modeled as water with a density of 0.0001 g/cm3). The SARP documents evaluation an infinite array of HUFPs with DFAs and an array of three HUFPs with IDENT-69G containers of loose fuel pins. The analyses include varied relative positions of the DFAs and IDENT-69G containers within the CCC tubes in addition to variations of the reflector around the HUFP.

The most reactive NCT payload is single package model (six IDENT-69G containers each filled with approximately 260 US/UK pins). No credit is taken for separation provided by the impact limiters.

The Staff confirms the validity of the Applicant's analysis configurations of the HUFP.

6.3.5.2 Results

Table 6.3-1 of this SER presents the Applicant's maximum reactivity results. The IDENT-69G container is the most reactive payload for the HUFP. An NCT array of three HUFPs with IDENT-69G containers is subcritical. An infinite NCT array of HUFPs with DFAs is subcritical. The most reactive array condition for the HUFP occurs with no water between the packages, because this condition maximizes communication between the packages. The Staff's analyses confirm the validity of the Applicant's criticality analyses of the HUFP.

6.3.6 Evaluation of Damaged-Package Arrays (Hypothetical Accident Conditions)

The HUFP conforms to the HAC criticality requirements for all packages given in 10 CFR 71.59(a)(2) and §71.59(a)(3).

6.3.6.1 Configuration

The Applicant evaluated only a single HUFP under HAC. The most reactive single package configuration is the HAC configuration.

6.3.6.2 Results

As noted above, the worst-case single package configuration is equivalent to the HAC configuration. Table 6.3-1 of this SER shows this. The Staff's analyses confirm the validity of the Applicant's criticality analyses of the HUFP.

6.3.7 Criticality Safety Index for Nuclear Criticality Control

The Applicant assigned a minimum Criticality Safety Index (CSI) of 100 to the HUFP. HAC calculations show that only a single package in any configuration has a multiplication factor plus bias and uncertainties that is less than the USL of 0.9304. The CSI value is consistent with that reported in Chapter 1 of the SARP. The Staff concurs that this CSI value is appropriate for the HUFP with the specified payloads.

6.3.8 Benchmark Evaluations

The SARP used the same criticality computer code, hardware and cross-section library sets to determine the bias values from benchmark experiments as those used to calculate the multiplication factors for the HUFP configurations. Section 6.8 of the SARP provides additional benchmark information.

6.3.8.1 Applicability of Benchmark Experiments

The benchmark experiments cited by the Applicant were taken from various volumes of the *International Handbook of Evaluated Criticality Safety Benchmark Experiments*[6-6] and are referenced appropriately. This collection of benchmark experiments is the accepted standard in the criticality community.

6.3.8.2 Bias Determination

Contributions from uncertainties in experimental data are included for all benchmark experiments reported in the Handbook. Also, a sufficient number of appropriate benchmark experiments are analyzed and the results of these benchmark calculations are used to determine an acceptable bias for the payload. These bias values are then used in the calculation of a safe multiplication factor for the package payloads. The statistical and convergence uncertainties of the benchmark calculations and package evaluations are essentially consistent, and do not significantly affect the determination of bias values.

The SARP determined an acceptable value for the bias for plutonium metal. Acceptable statistical analyses demonstrate that this value is accurate, but conservative. The Staff concurs that the benchmark experiments and corresponding bias value are applicable and conservative as applied to the HUFP.

6.3.9 Appendices

Section 6.9 of the SARP contains two appendices. Appendix 6.9.1 lists input files for the two worst-case single package (HAC) models (with DFA payload and with an IDENT-69G payload). Section 6.9.2 lists input files for the two worst case array models (infinite array with the DFA payload and a three-HUFP array with an IDENT-69G payload).

6.4 Evaluation Findings

6.4.1 Findings

Based on review of the statements and representations made in the SARP, the Staff concurs that the HUFP design has been shown to meet the criticality requirements of 10 CFR 71.31(a)(1), 10 CFR 71.31(a)(2), 10 CFR 71.33 and 10 CFR 71.35(a). The HUFP has also been shown to be designed, constructed and prepared for shipment so that there will be no significant reduction in the effectiveness of the packaging under the tests specified in §71.71 for NCT (i.e., §71.43(f), §71.51(a)(1), and §71.55(d)(4)).

The HUFP with specified payloads has been shown to meet the requirements of §71.55(b), §71.55(d) and §71.55(e), under which a single package must remain subcritical, and has been shown to meet the requirements of §71.59(a)(1) and §71.59(a)(2), under which an array of undamaged packages and an array of damaged packages, respectively, must remain subcritical.

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

6.4.2 Conditions of Approval

Section 6 of the certificate of compliance must contain the restriction that the HUFP must be constructed as specified on the engineering drawings given in the SARP. The CoC must also contain the restriction that HUFP contents are limited to the payloads described in Section 1.2.2 of the SARP. The package is not authorized for transport by air.

6.5 References

[6-1] Fluor Hanford, Inc., *Hanford Unirradiated Fuel Package (HUFP) Safety Analysis Report for Packaging*, HNF-28554, Revision 2, P.O. Box 1000, Richland, WA (August 2008).

[6-2] U.S. Nuclear Regulatory Commission, 10 CFR Part 71, *Packaging and Transportation of Radioactive Materials,* 01-01-2005 Edition.

[6-3] A.A. DiSabatino, et al., *Packaging Review Guide for Reviewing Safety Analysis Reports for Packagings*, UCID-21218, Revision 3, Lawrence Livermore National Laboratory (February 2008).

[6-4] A.H. Bridges and R.L. Reed, *Criticality Analysis of the HUFP with DFA and IDENT-69G (U)*, N-CLC-A-00070, Revision 0, Washington Safety Management Solutions LLC (December 2007).

[6-5] X-5 Monte Carlo Team, MCNP – A General Monte Carlo N-Particle Transport Code, Version 5; Volume II: User's Guide, LACP-03-0245, Los Alamos National Laboratory (April 2003).

[6-6] Nuclear Energy Agency, *International Handbook of Evaluated Criticality Safety Benchmark Experiments*, NEA Organization for Economic Co-Operation and Development, NEA/NSC Doc (95) 03 (September 2007).

7. PACKAGE OPERATIONS REVIEW

This section of the SER documents the review of Chapter 7, *Package Operations*, of the *Hanford Unirradiated Fuel Package (HUFP) Safety Analysis Report for Packaging (SARP)*[7-1] by DOE PCP Staff (the Staff). The review confirms that the operating procedures meet the requirements of 10 CFR 71,[7-2] and are adequate to assure that the package will be operated in a manner consistent with its evaluation for approval.

7.1 Areas of Review

The Staff reviewed the controls and procedures in the SARP to ensure that the HUFP will be operated in a manner consistent with its evaluation for approval. These are the generic operating procedures from which HUFP users will develop formal, site-specific operating procedures.

The Package Operations review includes the Areas of Review given in the Packaging Review Guide.[7-3]

7.2 Regulatory Requirements

The regulatory requirements of 10 CFR 71 applicable to the Package Operations review are those given in the Packaging Review Guide.[7-3]

7.3 Review Procedures

The following procedures are generally applicable to the review of the Package Operations chapter of the SARP. These procedures correspond to the Areas of Review listed in Section 7.1 of this SER. However, where appropriate, these requirements are supplemented by the guidance and/or the requirements specified in the *Guide for Preparing Operating Procedures for Shipping Packages* (NUREG/CR-4775).[7-4]

7.3.1 Package Loading

7.3.1.1 Preparation for Loading

Section 7.1 of the SARP specifies procedural steps for loading the HUFP. Section 7.1.1 and subsections cover preparation of the package for loading. The steps address the following considerations:

- SARP Section 7.1, 3rd paragraph states that the package will be loaded and closed in accordance with site-specific, written procedures.
- SARP Section 7.1, 2nd paragraph states that special controls and precautions for loading and handling include the following. Loading will be performed in a dry environment. Any free standing water will be removed prior to loading the payload.

- SARP Section 7.1.1.1, Step 3, states a requirement to verify that the package is unimpaired physically, and that all required periodic maintenance requirements have been performed,
- SARP Section 7.1.1.1, Step 5 states a specific requirement to ensure that the package is conspicuously and durably marked with the model number, serial number, gross weight, and package identification number.
- SARP Section 7.1.2.1, Step 3, states that the package must be proper for the contents to be shipped.
- SARP Section 7.1.2.1, Step 3 states a requirement to ensure that the use of the package complies with all other conditions of approval in the CoC.

7.3.1.2 Loading of Contents

Section 7.1.2 of the SARP specifies the procedural steps for loading HUFP contents into the Core Component Container (CCC). The steps address the following considerations:

- The SARP specifies special handling equipment where needed.
- The SARP specifies special controls and precautions for loading where needed.
- SARP Section 7.1.2.1, Steps 6-9 state the method for loading the contents.
- The SARP does not require the presence of moderator or neutron absorber materials.
- Although the SARP does not describe a method for removing water from the package, SARP Section 7.1, 2nd paragraph requires loading operations to be carried out in a dry environment, and requires removal of any free-standing water prior to loading the payload.
- The SARP doe not require venting gases from the package or adding a fill gas.
- The SARP specifies requirements to ensure that the closure devices of the package including seals and gaskets are properly installed, secured, and free of defects. SARP Section 7.1.2.1, Step 10 addresses the CCC, and SARP Section 7.1.2.3, Steps 1-5 address the Closure Lid.
- Bolt torques described in the procedures are consistent with those specified on the drawings:
  - CCC Lid to CCC Body – Section 7.1.2.1, Step 12 and Drawing 41199-50, Note 13
  - CCC Adapter Lid to CCC Adapter Lid Body – Section 7.1.2.2, Steps 7-8 and Drawing 41199-40, Note 5
  - Closure Lid to HUFP Body – Section 7.1.2.3, Step 7 and Drawing 41199-20, Note 8
  - Vent, Fill, and Seal Test Ports – Section 7.1.2.3, Step 9 (vent and fill), Step 9 (seal test), Drawing 41199-20, Note 13
  - Impact Limiters – Section 7.1.2.3, Step 14 and Drawing 41199-10, Note 4
- Based on the procedural steps stated in the SARP, the Staff has determined that the contents will be loaded correctly and that the package will be closed appropriately.

7.3.1.3 Preparation for Transport

Section 7.1.3 of the SARP specifies procedural steps for preparation for transport (loaded). The steps address the following considerations:

- SARP Section 7.1.1.1., Step 6, and Section 7.1.3 Step 2 ensures that the non-fixed (removable) radioactive contamination on the external surface of the package is as low as reasonably achievable and within the limits specified in 49 CFR §173.443.[7-5]
- SARP Section 7.1.3 Step 1 ensures that pre-shipment radiation surveys confirm allowable external radiation levels do not exceed those specified in 49 CFR §173.441.[6]
- SARP Section 7.1.3, Step 4 require a survey to verify that temperature limits specified in 10 CFR §71.43(g) are not exceeded.
- SARP Section 7.1.2.3, Step 11 and Section 7.4 require assembly-verification leakage rate testing of the vent port, fill port, and closure lid containment seals in accordance with ANSI N14.5-1997.[7-7]
- The HUFP design does not incorporate a system for containing liquids. SARP Section 7.1, 2nd paragraph requires loading operations to be carried out in a dry environment, and requires removal of any free-standing water prior to loading the payload.
- The HUFP design does not incorporate pressure relief devices.
- The HUFP design does not incorporate lifting or tie-down structures.
- SARP section 7.1.2.3, Step 19 requires installation of a tamper-indicating device.
- SARP Section 7.1.2.3, Steps 13-18 requires proper installation of impact limiters, personnel barriers, or similar devices.
- The SARP does not require special controls or precautions for transport, loading, unloading, or handling fissile material payloads nor any appropriate actions in case of an accident or delay. SARP Section 9.13, 2nd paragraph, states that shipment of the HUFP is to be carried out under the supervision of DOE couriers.
- The SARP does not require providing the HUFP carrier with special controls for shipment by exclusive use under the provisions of 10 CFR §71.47(b)(1). SARP Section 9.13, 2nd paragraph, states that shipment of the HUFP is to be carried out under the supervision of DOE couriers.
- The SARP does not require providing the HUFP carrier with special controls for the fissile-material package in accordance with 10 CFR §71.35(c). SARP Section 9.13, 2nd paragraph, states that shipment of the HUFP is to be carried out under the supervision of DOE couriers.
- The SARP does not require providing the consignee with special controls for opening the package.
- SARP Section 1.1, 3rd paragraph, states the HUFP Criticality Safety Index as 100 (one package per shipment).

7.3.2 Package Unloading

7.3.2.1 Receipt of Package from Carrier

Section 7.2.1 of the SARP presents procedural steps for receipt of the package from the carrier. The steps address the following considerations:

- SARP Section 7.2.1 includes specific procedures to ensure examination of the package for visible damage, status of the tamper-indicating device, surface contamination, and external radiation levels.
- SARP Section 7.2.1 includes specific procedures describing special actions to be taken if the package is damaged, if the tamper-indicating device is not intact or if surface contamination or radiation survey levels are too high.
- The SARP does not require special handling equipment for unloading the package. However, SARP Section 7.2 refers the user to Section 2.1.3 and Table 2.1-3 for the HUFP component weights and centers-of-gravity, including the weight of the transportation skid, to ensure the use of properly rated lifting equipment.
- SARP Section 7.2, 2nd paragraph, requires unloading the HUFP in a dry environment.

7.3.2.2 Removal of Contents

Section 7.2.2 of the SARP presents procedural steps for removal of package contents. The steps address the following considerations:

- SARP Sections 7.2.2.2 through 7.2.2.4 describe the appropriate method for opening the package.
- SARP Sections 7.2.2.5 through 7.2.2.4 describe the appropriate method for removing the package contents.
- SARP Section 7.2.2.5, Step 7 ensures complete removal of the package contents.

7.3.3 Preparation of Empty Package for Transport

Section 7.3 of the SARP presents procedural steps for the preparation of an empty packaging for transport. The steps address the following considerations:

- The SARP requires specific procedures to verify that the package is empty.
- The SARP requires specific procedures to ensure that the external surface contamination levels meet the requirements given in Appendix D of 10 CFR 835. Similarly, the SARP requires specific procedures to ensure that an internally-contaminated, empty package is prepared for shipment as specified in 49 CFR 173.421[7-8] or 49 CFR 173.428,[7-9] depending on the level of residual contamination.
- The SARP requires specific procedures for closure of an empty package. Bolt torque requirements for an empty CCC (65 – 75 lbf-ft) are reduced compared to a loaded CCC (145 – 155 lbf-ft). However, the bolt torque requirements of the CCC-Adapter (70 – 75 lbf-ft), HUFP closure lid (175 – 220 lbf-ft) and impact limiter bolts (180 –220 lbf-ft) are unchanged.

- The SARP requires specific procedures for shipment of an Empty Radioactive Materials Packaging in accordance with 49 CFR 173.428 -- the labels and the nameplate must be covered with tape and the package must be marked *Empty*.

7.3.4 Additional Procedures

SARP Sections 7.4 and 7.5 describe Other Operations: Pre-shipment Leakage Rate Tests, and Operational Sketches, respectively.

- SARP Sections 7.4.1 through 7.4.4 describe procedures for pre-shipment leakage rate testing of the HUFP per ANSI N-14.5.
- SARP Section 7.5 provides supplemental information (i.e., photos and sketches) to aid package users including an air pallet, an up-righting device, and a sealing surface protector.

7.3.5 Appendices

Chapter 7 of the HUFP SARP does not include Appendices.

7.4 Evaluation Findings

7.4.1 Findings

The Staff reviewed the operating procedures presented in the SARP for completeness and compliance with the regulatory requirements. The Applicant provided information in the format prescribed directly by NRC Regulatory Guide 7.9,[7-10] not in the format outlined in NUREG/CR-4775. However, the Package Operations chapter of the SARP presented applicable information in the appropriate level of detail, including operating requirements, general information, package loading, shipment preparation, package receipt and package unloading. Chapters 2, 4, 8 and 9 of the SARP provide supplemental information in the appropriate level of detail on inspection and maintenance and on records and reporting requirements, respectively.

Based on the review of the statements and representations presented in the application, the Staff concludes that HUFP operating procedures meet the requirements of 10 CFR 71, 49CFR173, and DOE Order 460.1B [7-11] and that the procedures are adequate to assure the package will be operated in a manner consistent with its evaluation for approval.

7.4.2 Conditions of Approval

Because they represent the framework from which HUFP users/shippers will develop formal, site-specific operating procedures, the Staff concludes that the procedural steps for operating the HUFP specified in Chapter 7 of the SARP should be incorporated in their entirety into the Certificate of Compliance as a condition of package approval.

7.5 References

[7-1] Fluor Hanford, Inc., *Hanford Unirradiated Fuel Package (HUFP) Safety Analysis Report for Packaging*, HNF-28554, Revision 2, P.O. Box 1000, Richland, WA (August 2008).

[7-2] U.S. Nuclear Regulatory Commission, 10 CFR Part 71, *Packaging and Transportation of Radioactive Materials,* 01-01-2005 Edition.

[7-3] A.A. DiSabatino, et al., *Packaging Review Guide for Reviewing Safety Analysis Reports for Packagings*, UCID-21218, Revision 3, Lawrence Livermore National Laboratory (February 2008).

[7-4] U.S. Nuclear Regulatory Commission, *Guide for Preparing Operating Procedures for Shipping Packages*, NUREG/CR-4775 (July 1988).

[7-5] U.S. Department of Transportation, *Contamination Control*, Code of Federal Regulations, Title 49, Part 173.443, Washington, DC (October 2007).

[7-6] U.S. Department of Transportation, *Radiation Level Limitations and Exclusive Use Provisions*, Code of Federal Regulations, Title 49, Part 173.441, Washington, DC (October 2007).

[7-7] American National Standards Institute, Inc., American National Standard for Radioactive Materials - Leakage Tests on Packages for Shipment, ANSI N14.5-1997 New York (1997).

[7-8] U.S. Department of Transportation, *Excepted Packages for Limited Quantities of Class 7 (Radioactive) Materials*, Code of Federal Regulations, Title 49, Part 173.421, Washington, DC (October 2007).

[7-9] U.S. Department of Transportation, *Empty Class 7 (Radioactive) Materials Packaging*, Code of Federal Regulations, Title 49, Part 173.428, Washington DC (October 2007).

[7-10] U.S. Nuclear Regulatory Commission, *Standard Format and Content Guide of Part 71 Applications for Approval of Packaging for Radioactive Material*, Regulatory Guide 7.9, Revision 3, Washington , DC (March 2005).

[7-11] U.S. Department of Energy, Packaging and Transportation Safety, DOE O 460.1B, Washington, DC (April 2003).

8. ACCEPTANCE TESTS AND MAINTENANCE PROGRAM REVIEW

This section of the SER documents the review of Chapter 8, Acceptance Tests and Maintenance Program of the *Hanford Unirradiated Fuel Package (HUFP) Safety Analysis Report for Packaging(SARP)*[8-1] by DOE PCP Staff (the Staff). The review confirms that the Acceptance Tests meet the requirements of 10 CFR 71,[8-2] and that the Maintenance Program is adequate to assure regulatory-compliant packaging performance during its service life. Commitments specified in the Acceptance Tests and Maintenance Program chapter of the SARP are typically included in the CoC as conditions of package approval.

8.1 Areas of Review

The Acceptance Tests and Maintenance Program review includes the Areas of Review given in the Packaging Review Guide.[8-3]

8.2 Regulatory Requirements

The regulatory requirements of 49 CFR 172 and 10 CFR 71 applicable to the Acceptance Tests and Maintenance Program review and are those cited in the Package Review Guide.[8-3]

8.3 Review Procedures

The following procedures are applicable to the review of the Acceptance Tests and Maintenance Program Chapter of the SARP for the HUFP. In general, these procedures correspond to the Areas of Review listed in Section 8.1 of this SER. Where appropriate, however, these requirements are supplemented by the guidance and/or the requirements specified in *Fabrication Criteria for Shipping Containers* (NUREG/CR-3854),[8-4] *Welding Criteria for Use in the Fabrication of Radioactive Material Shipping Containers* (NUREG/CR-3019),[8-5] and the *American National Standard for Radioactive Material-Leakage Tests on Packages for Shipment* (ANSI N14.5).[8-6]

8.3.1 Acceptance Tests

Chapter 8 of the SARP states that Acceptance Tests are performed prior to the first use of each newly fabricated package. Where applicable, the review cites references to sections of the Quality Assurance program (Chapter 9 of the SARP) and the Package Operations (Chapter 7 of the SARP).

8.3.1.1 Visual Inspections and Measurement

The applicant has required completion of inspections based on drawings associated with the latest certified HUFP design prior to first use of the package. As part of the acceptance criteria, the applicant has required the owner to perform visual inspections (and/or measurements) addressing the outer shell, body assembly, closure lid, impact limiters, test ports, the packaging nameplate and the associated barcode plate, etc. (Section 8.1.1 and Appendix 8.3.1 of the SARP.)

8.3.1.2 Weld examinations

The applicant has required examination of containment welds in accordance with the applicable drawings in Appendix 1.3.2 of Chapter 1 of the SARP. The applicant has specified the ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, 2001 Edition with 2002 and 2003 Addenda as the code of record.[8-7] The HUFP drawings specify nondestructive examinations and acceptance criteria in accordance with the appropriate code requirements and confirmation of the location, type, and size of welds by measurement.

8.3.1.3 Structural and Pressure Tests

The applicant has specified that the owner will verify completion of pressure-proof testing of the containment vessel to at least 1.25 times the design pressure in accordance with ASME Section III, Subsection NB. For the HUFP, the corresponding pressure is 31.25 psig which bounds the pressure test of 150% of MNOP, or 15 psig, required by 10 CFR 71.85(b). Following proof testing, the containment boundary is inspected (Section 8.1.3.2 of the SARP).

8.3.1.4 Leakage Tests

The applicant has specified that the HUFP containment boundary shall be leak-rate tested with helium, in accordance the applicable gas-filled-envelop or evacuated-envelope method described in Appendices A.5.3 and A.5.4 of ANSI N14.5. The applicant has further specified that the test results must demonstrate a leak rate less than 1×10^{-7} ref cm^3/sec (air) with a test sensitivity of less than 5×10^{-8} ref cm^3/sec, in accordance with the ANSI N14.5 definition of *leaktight*.

8.3.1.5 Component and Materials Tests

8.3.1.5.1 Component Tests

The applicant has specified testing of chemical, physical, and thermal performance of the polyurethane foam used in the impact limiters (Section 8.1.5 of the SARP). The tests required are equivalent to those invoked for other packaging designs that utilize polyurethane foam.

8.3.1.5.2 Materials Tests

Chapter 2 of the SARP discusses materials material testing and acceptance criteria. The HUFP drawings identify applicable sections of the ASME Code governing ASME Code materials. Completion of materials tests and examinations are required prior to installation or first use.

8.3.1.6 Tests for Shielding Integrity

The applicant has stated that no shielding integrity testing is required for acceptance of the packaging. The HUFP design does not include dedicated shielding materials.

8.3.1.7 Thermal Acceptance Tests

The applicant has stated that no thermal testing beyond that conducted on the polyurethane foam is required for acceptance of the packaging.

8.3.1.8 Miscellaneous Tests

The HUFP drawings specify inspections and examinations, and Appendix 8.3.1 specifies inspection criteria to assure compliance with 10 CFR 71.85(a), (b) and (c). Appendix 8.3.1 requires weld inspections and examinations, leak-testing, pressure testing, and nameplate information.

8.3.2 Maintenance Program

Performance of Maintenance Program tests ensures that packaging effectiveness is maintained throughout its service life. Where applicable, the review cites references to sections of the Quality Assurance program (Chapter 9 of the SARP) and the Package Operations (Chapter 7 of the SARP).

8.3.2.1 Structural and Pressure Tests

The applicant has stated that no annual structural or pressure testing is required for the HUFP. However, the applicant requires recurrent structural pressure testing of the containment vessel every five years (Section 8.1.2 of the SARP). The applicant has stated that replacement of the O-rings with equivalent components does not require pressure testing of the containment vessel.

8.3.2.2 Leakage Tests

The applicant has provided procedures for required leak-rate testing of the HUFP containment boundary (Section 8.2.2 of the SARP). Test and acceptance criteria are identical to those for Fabrication Leakage Rate Tests (Section 8.1.4.1 of the SARP).

8.3.2.2.1 Main O-Ring Seal

The applicant has specified Maintenance/Periodic Leakage Rate Tests requirements for the Main O-Ring Seal using the Evacuated-Envelope Gas Detector method of ANSI N14.5.

8.3.2.2.2 Vent Port Plug Seal Washer

The applicant has specified Maintenance/Periodic Leakage Rate Tests requirements for the Vent Port Plug Washer using the Evacuated-Envelope Gas Detector method of ANSI N14.5.

8.3.2.2.3 Fill Port Plug Seal Washer

The applicant has specified Maintenance/Periodic Leakage Rate Tests requirements for the Fill Port Seal Washer using the Evacuated-Envelope Gas Detector method of ANSI N14.5.

8.3.2.3 Component and Materials Tests

8.3.2.3.1 Component Tests

The applicant has specified visual inspection of the sealing surfaces and O-rings prior to closure. The inspection seeks gouges, nicks, cuts, cracks or scratches that could affect containment performance (Section 7.1.2.3 of the SARP). Inspected components are to be repaired or replaced before installation or entering service (Section 8.2.3 of the SARP). Components include fasteners, seal areas and grooves, impact limiters, seals, core component container (CCC) and

CCC adapter. The applicant has also specified replacement of all containment seals annually or when damaged. Criteria for inspections of components are identified as follows:

Fasteners
The applicant has specified visual inspection of threaded components for deformed or stripped threads and repair or replacement of damaged threaded components (Section 8.2.3.1 of the SARP).

Seal Areas and Grooves
The applicant has specified that sealing surfaces be visually inspected for damage that could impair sealing capabilities of the HUFP. Damaged areas shall be repaired before use (Section 8.2.3.2 of the SARP).

Impact Limiters
The applicant has specified visual inspection of the impact limiters for tears or perforations of their stainless steel sheath and for presence of the plastic plugs (Section 8.2.3.3 of the SARP).

Seals
The applicant has specified that all containment seals be replaced annually or when damaged and leakage rate tested following seal replacement and prior to next loaded shipment (Section 8.2.3.4 of the SARP).

Core Component Container
The applicant has specified visual inspection for damage and integrity of the lifting points and of the seal area prior to each use of the CCC (Section 8.2.3.5 of the SARP).

Core Component Container Adapter
The applicant has specified visual inspection of the threads of the six CCC-Adaptor lid-to-body attachment holes for damage and specified repair of any damage before use (Section 8.2.3.6 of the SARP).

8.3.2.3.1 Materials Tests

Section 2.2 of the SARP discusses the properties of structural materials used in the construction of the HUFP. The applicant states that there are no significant chemical or galvanic reactions of the major structural materials of the HUFP and that these structural materials are not affected significantly by radiation. Further, the HUFP design does not incorporate dedicated shielding materials (Section 5.0 of the SARP). The applicant has stated that no annual maintenance is required for the shielding-related attributes of the HUFP.

8.3.2.4 Thermal Tests

The applicant has stated that no annual maintenance is required for thermal features of the HUFP (Section 8.2.4 of the SARP).

8.3.2.5 Miscellaneous Tests

The applicant has stated that no miscellaneous tests are required to ensure continued performance the HUFP (Section 8.2.5 of the SARP).

8.3.3 Appendices

Chapter 8 of the SARP includes two Appendices described as follows.

Section 8.3.1, *Inspection Criteria for Acceptance of Newly Fabricated Hanford Unirradiated Fuel Packages*. The requirements specified therein include the principal acceptance criteria given on the drawings, as well as essential operational requirements. These Criteria are supplemented by the requirements of Appendix 8.3.2.

Section 8.3.2, *Independent Verification Items for Acceptance of Newly Fabricated Hanford Unirradiated Fuel Packages*. The requirements specified therein provide cross-linkage between the Acceptance criteria specified in the SARP, the Drawings given in Appendix 1.3.2 of the SARP, and the Quality Assurance requirements specified in the SARP.

8.4 Evaluation Findings

8.4.1 Findings

The Staff has reviewed the Acceptance Tests and Maintenance Program information presented in the HUFP SARP for completeness and for compliance with regulatory requirements. The applicant provided relevant information in the format prescribed by NRC Regulatory Guide 7.9.[8-8] The applicant also provided appropriately detailed supplemental information about inspections and maintenance and about records and reporting requirements in Chapters 7 and 9 of the SARP, respectively.

Based on the Staff's review of the statements and representations given in the application, the Staff concludes that the Acceptance Tests for the Hanford Unirradiated Fuel Package meet the requirements of 10 CFR 71, and that the Maintenance Program is adequate to assure regulatory-compliant packaging performance during its service life. The Staff also concludes that the information provided for the Acceptance Tests and Maintenance Program is adequate.

8.4.2 Conditions of Approval

As was noted in the introduction to this section, commitments specified in the Acceptance Tests and Maintenance Program chapter of the SARP are typically included in the certificate of compliance as a condition of package approval. The Staff concurs and recommends incorporation in its entirety of the Acceptance Tests and Maintenance Program Chapter (Chapter 8) of the SARP into the CoC as a condition of package approval.

8.5 References

[8-1] Fluor Hanford, Inc., *Hanford Unirradiated Fuel Package (HUFP) Safety Analysis Report for Packaging*, HNF-28554, Revision 2, P.O. Box 1000, Richland, WA (August 2008).

[8-2] U.S. Nuclear Regulatory Commission, 10 CFR Part 71, *Packaging and Transportation of Radioactive Materials,* 01-01-2005 Edition.

[8-3] A.A. DiSabatino, et al., *Packaging Review Guide for Reviewing Safety Analysis Reports for Packagings*, UCID-21218, Revision 3, Lawrence Livermore National Laboratory (February 2008).

[8-4] U.S. Nuclear Regulatory Commission, *Fabrication Criteria for Shipping Containers*, NUREG/CR-3854 (UCRL-53544) (March 1985).

[8-5] U.S. Nuclear Regulatory Commission, *Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials*, NUREG/CR-3019 (UCRL-53044) (March 1984).

[8-6] American National Standards Institute, Inc., American National Standard for Radioactive Materials - Leakage Tests on Packages for Shipment, ANSI N14.5-1997 New York (1997).

[8-7] American Society of Mechanical Engineers Boiler and Pressure Vessel Code, *Section III, Rules for Construction of Nuclear Power Plant Components, Division 1, Subsection NB, Class 1 Components*, 2001 Edition, 2002 and 2003 Addenda. (More recent editions/addenda may be used for fabrication.)

[8-8] U.S. Nuclear Regulatory Commission *Standard Format and Content of Part 71 Applications for Approval of Packaging for Radioactive Material*, Regulatory Guide 7.9, Revision 3, Washington, DC (March 2005).

9. QUALITY ASSURANCE REVIEW

This section of the SER documents the review of Chapter 9, Quality Assurance, of the *Hanford Unirradiated Fuel Package (HUFP) Safety Analysis Report for Packaging (SARP)*[9-1] by DOE PCP Staff (the Staff). The review includes an evaluation of the SARP with respect to the requirements specified in 10 CFR 71.[9-2]

9.1 Area Reviewed

The Quality Assurance review includes the Areas of Review given in the Packaging Review Guide.[8-3]

9.2 Regulatory Requirements

The regulatory requirements of 10 CFR 71 applicable to the Quality Assurance review are those given in the Packaging Review Guide.[9-3]

9.3 Review Procedures

The following subsections describe the review methods for the Areas of Review applicable to the Quality Assurance Chapter of the SARP. These procedures correspond to the *Elements Reviewed*, listed above in Section 9.1.

9.3.1 Description of Applicant's QA Program

9.3.1.1 Scope

Chapter 9 of the SARP states that the QA program complies with 10 CFR 71, Subpart H, and is applied to package-related activities, including procurement activities consistent with the applicable regulatory requirements. The introductory text to Chapter 9, *Preface*, describes the QA requirements for the design, procurement, fabrication, handling, shipping, storage, cleaning, assembly, inspection, testing, operation, maintenance, repair and modification of the HUFP that comply with 10 CFR 71, Subpart H, and that are important to safety. Section 9.1 of the SARP describes the applicant's organization, including the QA organizations and their responsibilities relative to implementation of the QA program.

9.3.1.2 Program Documentation and Approval

As required by §71.31(a)(3) and §71.37, Section 9.2.1 of the SARP identifies that the Flour Hanford Quality Assurance Program Description (FH-QAPD),[9-4] documents the QA program that complies with 10 CFR 71, Subpart H, as well as 10 CFR 830, Subpart A,[9-5] DOE Order 414.1.C,[9-6] DOE Order 460.1B,[9-7] and NQA-1. The Fluor Hanford Transportation and Packaging Quality Assurance Program Plan,[9-8] identifies the procedures for implementing the QAPD. Additional information on the hierarchy and relationship of requirements documents, the FH QA Program Description and implementing procedures is provided in Figure 9.2-1 of the

SARP. The current revision and date of the applicable FH QA documents are provided in the references section in Chapter 9 of the SARP.

9.3.1.3 Summary of 18 Quality Assurance Requirements from 10 CFR 71, Subpart H

The FH QAPD and FH Transportation and Packaging Quality Assurance Program Plan sections (that include the quality implementing procedures) implementing each of the 18 QA requirements of 10 CFR 71, Subpart H are listed and summarized in Table 9.1-1 of the SARP. Chapter 9 describes the provisions in the QA Program Manual sections, as they apply to the scope of the applicant's responsibilities, identified in Section 9.3.1.1, above.

9.3.1.4 Cross-Referencing Matrix

Table 9.1-1 of the SARP provides a cross-referencing matrix that links each of the 18 QA requirements of 10 CFR 71 Subpart H to the corresponding FH QAV Program Manual(s) sections. A direct correlation exists between the 18 QA requirements of Subpart H and the sections of FH QA Program Manual.

9.3.2 Package-Specific QA Requirements

9.3.2.1 Graded Approach for Structures, Systems, and Components Important to Safety

Per §71.101(b), Section 9.2.3 of the SARP describes the graded application of the FH Quality Assurance Manual(s) to package structures, systems, and components (SSCs) that are important to safety. Safety-related "Q" packaging components are categorized as A, B, or C, with Category A items having the largest impact on safety. Table 9.2-1 of the SARP correlates the FH Safety Designations for "Q" and "non-Q" (not related to safety) for the HUFP to the safety designations in the NRC's Regulatory Guide 7.10.[9-9]

Packaging SSCs and their Q categories, functions and drawing number (e.g., name and part number) are provided in Table 9.2-2 of the SARP.

Table 9.2-3 of the SARP identifies the graded level of QA controls that apply to Q categories A, B, and C, consistent with the requirements in §71.101(b) and the guidance in Reg. Guide 7.10.

9.3.2.2 Package-Specific Quality Criteria and Package Activities

Per §71.31(a)(3) and §71.37, the SARP describes the QA controls in each section of the FH QA Program Manual listed in Table 9.1-1, and describes how these controls are applied to HUFP activities related to the design, procurement, fabrication, handling, shipping, storage, cleaning, assembly, use, inspection, acceptance testing, maintenance, repair, and modification of the HUFP. The graded approach, described in Section 9.3.2.1 above, is used to selectively apply the QA controls to package SSCs based on their importance to safety.

As required by §71.31(a)(3) and §71.37, Table 9.3-1 of the SARP details the materials, design, fabrication, testing, examination, QA program and records requirements for the Packaging Containment Vessels that conform to Section III, Division 1, Subsection NB, of the ASME Boiler and Pressure Vessel Code (B&PV).[9-10] Table 9.3-2 of the SARP details the materials, design, fabrication, examination, QA program and records requirements for the Drum Bolted Flange Closure that conform to Section III, Division 1, Subsection NF, of the ASME

B&PV Code.[9-11] Table 9.3-3 of the SARP details the materials, design, fabrication, examination, QA program and records requirements for the Package Core Support Components that conform to Section III, Division 1, Subsection NG, of the ASME B&PV Code.[9-12]

Section 9.6 of the SARP identifies documents that are controlled to ensure correct documents are used, and that records requirements are met. Controlled documents include operating procedures (SARP Chapter 7), procurement documents (SARP Section 9.4), and the inspection (SARP Section 9.10), testing, and maintenance documents (SARP Chapter 8 and Section 9.11 of the SARP).

Section 9.15 defines the controls for documenting, resolving, and preventing the recurrence of package-related non-conformances. Section 9.15 also includes provisions for obtaining FH Design Authority and Design Agency approval of nonconformance dispositions, and reporting package defects that significantly reduce safety performance of the package to the DOE Certifying Authority in accordance with §71.95.

Section 9.17 summarizes the provisions for ensuring sufficient written records are maintained to furnish evidence of the quality of the HUFP. The records and their retention requirements, identified in Section 9.17 and Table 9.17-1 of the SARP, are consistent with §71.85, §71.91(b), and §71.91(d).

9.3.3 Appendices

Section 9.19 of the SARP lists the associated Appendices.

9.4 Evaluation Findings

9.4.1 Findings

Based on review of the statements and representations in the SARP, the Staff concludes that the applicant's QA program has been adequately described and meets the QA requirements of 10 CFR 71. Package-specific QA requirements are adequate to assure that the package is designed, fabricated, assembled, tested, used, maintained, modified, and repaired in a manner consistent with its evaluation.

9.4.2 Conditions of Approval

Any organization involved in the design, procurement, fabrication, handling, shipping, storage, cleaning, assembly, operation, inspection, testing, maintenance, repair, modification, and use of the HUFP shall maintain and follow an appropriate QA program that is compliant with the requirements specified in 10 CFR 71, Subpart H. For non-FH users, this shall include compliance with the package-specific QA requirements specified in Chapter 9 of the SARP.

9.5 References

[9-1] Fluor Hanford, Inc., *Hanford Unirradiated Fuel Package (HUFP) Safety Analysis Report for Packaging*, HNF-28554, Revision 2, P.O. Box 1000, Richland, WA (August 2008).

[9-2] U.S. Nuclear Regulatory Commission, 10 CFR Part 71, *Packaging and Transportation of Radioactive Materials,* 01-01-2005 Edition.

[9-3] A.A. DiSabatino, et al., *Packaging Review Guide for Reviewing Safety Analysis Reports for Packagings*, UCID-21218, Revision 3, Lawrence Livermore National Laboratory (February 2008).

[9-4] Fluor Hanford, Inc., *Quality Assurance Program Description*, HNF-MP-599, Richland, WA.

[9-5] U.S. Department of Energy, 10 CFR Part 830, *Nuclear Safety Management*, 66 F.R. 1818, pp. 1818-1827, January 10, 2001, as amended. See, in particular, Subpart A, *Quality Assurance Requirements*, pp. 1820–1821, as amended.

[9-6] U.S. Department of Energy, *Quality Assurance*, DOE O 414.1C, , Washington, DC (June 2005).

[9-7] U.S. Department of Energy, *Packaging and Transportation Safety*, DOE O 460.1B, Washington, DC (April 2003).

[9-8] Fluor Hanford, Inc., *Transportation and Packaging Quality Assurance Program Plan*, HNF-25689, Richland, WA.

[9-9] U.S. Nuclear Regulatory Commission *Establishing Quality Assurance Programs for Packaging Used in the Transport of Radioactive Material*, Regulatory Guide 7.10, Revision 2, Washington, DC (March 2005).

[9-10] American Society of Mechanical Engineers, *Rules for Construction of Nuclear Facility Components, Boiler and Pressure Vessel Code, Section III*, Division 1, Subsections NB, *Class I Components*, (2001).

[9-11] American Society of Mechanical Engineers, *Rules for Construction of Nuclear Facility Components*, Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NF, *Supports*, (2001).

[9-12] American Society of Mechanical Engineers, *Rules for Construction of Nuclear Facility Components, Boiler and Pressure Vessel Code*, Section III, Division 1, Subsections NG, Class I *Components*, (2001).