Safety Evaluation Report for Revision 1 of the Addendum to the Consolidated Safety Analysis Report for Packaging for the T-3 Spent Fuel Shipping Cask FFTF-30866

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Prepared by: James M. Shuler Date: 7/19/7

James M. Shuler
Manger, Packaging Certification Program
Safety Management and Operations
Office of Environmental Management

Approved by: [signature] Date: 7/19/07

Dae Y. Chung
Headquarters Certifying Official
Safety Management and Operations
Office of Environmental Management

Overview

This Safety Evaluation Report (SER) documents the review, performed by the EM-60 staff the *Addendum to the Consolidated Package Safety Analysis Report for the T-3 Spent Fuel Shipping Cask Demonstrating Compliance to the Requirements of 10 CFR 71, Sodium-Bonded Fuel*, Revision 1, FFTF-30866 dated June 2007 (the Addendum).[1] The T-3 Shipping Cask is certified by DOE Certificate of Compliance (CoC)[2] number USA/9132/B(M)F for the transportation of Type B quantities of spent fuel containing sodium, uranium, zirconium, and plutonium. The safety analysis of the package is documented in the *Consolidated Safety Analysis Report (SAR) for the T-3 Spent Fuel Shipping Cask* (i.e., the T-3 SAR, or the SARP).[3]

The Addendum describes the addition of a supplemental vessel (the 6CVL or T-3/6CVL Independent Fuel Canister Containment Vessel Assembly) to the existing T-3 Cask cavity. The 6CVL is an independent stainless steel (SS) pressure vessel designed, analyzed, and fabricated in accordance with the American Society of Mechanical Engineers Boiler and Pressure Vessel (ASME B&PV) Code, Section III, Subsection NB[4]. The additional canister/containment vessel assembly, as an independent containment vessel, precludes the in-leakage of water into the new canister/containment cavity and meets the provisions outlined in the Nuclear Regulatory Commission's (NRC), Interim Staff Guidance (ISG) document, ISG-1[5]. This additional level of safety is required because the special shipments requested will have increased sodium-bonded fuel payloads exceeding the limits set by the existing CoC as follows:

- An increase in the maximum number of loose, sodium-bonded metal fuel pins per shipment from 18 to 80;
- An increase in the maximum mass of sodium per shipment from 200 grams to 1,525 grams; and
- Additional confinement of loose fuel pins.

This report documents the EM-60 staff review of the Addendum. Based on the review of the statements and representations in the Addendum, the Staff has concluded that the design and performance of the 6CVL with the intended payloads have been adequately demonstrated to meet the requirements of 10 CFR 71[6] and the International Atomic Energy Agency's Safety Standards Series No. TS-R-1.[7] The specific review of each SARP Chapter is documented herein.

Chapter 1: General Information

This section of the Safety Evaluation Report (SER) covers the review of the General Information provided in Chapter 1 of the Addendum.[1] The applicant requests authorization to package and ship larger numbers of sodium-bonded binary and ternary metal fuel pins as contents in the form of fuel pins and fuel assemblies (the fuel assemblies are all sodium-bonded binary metal payloads) listed as Type 13 in the existing Certificate of Compliance (CoC).[2] As described in the Addendum, using schematic and engineering drawings including Figures 1.1 through 1.4, individual fuel pins and fuel assemblies will be contained within the new inner vessel, a 6CVL Independent Fuel Canister Containment Vessel Assembly (6CVL), that is accommodated by the existing T-3 Shipping Cask.

The T-3 Shipping Cask is certified by DOE Certificate of Compliance (CoC) number USA/9132/B(M)F for the transportation of Type B quantities of spent fuel containing sodium, uranium, zirconium, and plutonium. The safety analysis of the package is documented in the *Consolidated Safety Analysis Report (SAR) for the T-3 Spent Fuel Shipping Cask* (i.e., the T-3 SAR, or the SARP)[3].

Many shipments of mixed oxide fuels have been made over the years with the T-3 Shipping Cask. This SER, however, focuses on review of the 6CVL and its special contents. The 6CVL vessel serves as the primary containment for precluding water in-leakage and interaction with the sodium in the special contents and as a canister for confining damaged metal fuel pins per the Nuclear Regulatory Commission's (NRC's) Interim Staff Guidance-1 (ISG-1) for Damaged Fuel from the Spent Fuel Project Office of the NRC.[5] Individual fuel pins are further constrained by the 6CVL Inner Pin Container Assembly (IPCA) located inside the 6CVL. Tables 1.2 and 1.4 in the Addendum describe the various sodium-bonded metal fuel pins and metal fuel assemblies, respectively. Some fuel pins have been irradiated while others are unirradiated. The same statement is true of the fuel assemblies.

The following limits and conditions apply to the proposed contents with respect to the existing CoC:

- An increase in the maximum number of loose, sodium-bonded metal fuel pins per shipment from 18 to 80;
- An increase in the maximum mass of sodium per shipment from 200 grams to 1,525 grams;
- Additional confinement of loose fuel pins within a canister identified as the 6CVL Inner Pin Container Assembly (the ICPA);
- Containment of the IPCA within a robust pressure vessel that provides an independent, leak-testable containment boundary (i.e., the 6CVL);
- Containment of a single, cropped metal fuel assembly (housing 169 sodium-bonded metal fuel pins) within the same containment vessel; and
- Limiting the maximum decay heat from either of the proposed payloads to 150 watts.

Description of Binary and Ternary Metal Fuel

Binary metal fuel consists of uranium and zirconium with sodium added for purposes of enhancing heat transfer. The maximum concentration of ^{235}U in this fuel is 34wt%. Ternary fuel is composed of uranium, plutonium, and zirconium with sodium again added to aid heat transfer. The concentration of ^{235}U ranges from 4.5wt% to 17.5wt%. Total uranium varies from 70wt% to 82wt%. Correspondingly, plutonium ranges from 20wt% to 8wt% (the ^{240}Pu content is 5.8wt%). The bounding activity for the fuel is 49,400 A_2.

Description of the 6CVL

The 6CVL is a stainless steel (SS) pressure vessel designed, analyzed, and fabricated in accordance with the American Society of Mechanical Engineers Boiler and Pressure Vessel (ASME B&PV) Code, Section III, Subsection NB.[4] The vessel is fabricated from 6-inch, Schedule 40S, seamless, Type 304L SS pipe (0.280-inch nominal wall), and incorporates a standard Schedule 40S Type 304L SS pipe cap (also 0.280-inch nominal wall) at the blind end. A stayed head is machined from a 7½-inch diameter by 2¼-inch long Type 304L SS bar and welded to the open end of the pipe. The head is further machined to include 6½-12UNS-2B internal threads and a female cone-seal surface with a 32-μin finish.

A stainless steel plug closes the vessel by mating with the sealing surface of the body. The plug, called the cone-seal plug, incorporates two machined circumferential O-ring grooves and between the O-ring grooves a machined circumferential test groove for leak-rate testing. A cone-seal nut holds the cone-seal plug in place and establishes the compression force for sealing the closure. The leak-test port is closed by a special ¼-inch 316 SS plug held in place by a gland nut fabricated from 410 SS.

The 6CVL Containment Vessel closure seal incorporates two concentric fluoro-elastomeric O-rings that fit into the circumferential grooves machined into the cone-seal plug. The inner O-ring serves as part of the supplemental containment boundary. The location of the outer O-ring forms a small external volume to facilitate leak-rate testing of the inner O-ring. The outer O-ring is not part of the supplemental containment boundary, but it does present an additional and significant barrier to the release of package contents.

The overall length of the closed vessel is 136.6 inches. The volume of the cavity is about 3,780 cubic inches. The usable length and diameter of the 6CVL cavity are approximately 129 inches and 6 inches, respectively. The 6CVL weighs about 259 lb empty and 646.5 lb loaded with the heaviest payload. An aluminum support pedestal at the blind end of the vessel provides a flat supporting surface for an IPCA or cropped metal fuel assembly.

A Dual-Handling Socket (DHS) assembly is used for manipulating the 6CVL inside the Interim Examination Facility and transfer cell of the Fast Flux Transfer Facility (FFTF). The DHS remains with the 6CVL for shipment. A Handling Socket Assembly is a component of the IPCA in addition to the Body Assembly. It also remains with the IPCA for shipment.

Sodium Removal System

In the Sodium Removal System, sodium metal is removed from the surface of irradiated individual fuel pins and irradiated fuel assemblies using water and by reaction with water followed by a stream of hot argon. The atmosphere within the 6CVL is dry argon. The atmosphere in the T-3 Shipping Cask can be dry argon or dry nitrogen with up to 4% argon. When the Addendum was originally submitted for review, the facility was considering converting from argon to nitrogen. At the present and probably through the life of this CoC, it appears the plant will remain on argon. EM-60 staff conducted a confirmatory analysis and concluded that either argon or nitrogen could be used.

The Criticality Safety Index is 0 for shipments.

The Addendum summarizes the two proposed payloads as follows:

- The maximum mass of fissile material in the proposed payload is 34.66 lb ^{235}U or 24.9 lb of ^{239}Pu and ^{235}U in the ratio of 5.98:1;
- The nominal expected weight of the loose fuel pins payload is 588 lb, including radioactive materials (80 sodium-bonded fuel pins), IPCA and 6CVL. This payload weight is less than the 700 lb evaluated in the SARP;

- The nominal expected weight of a cropped metal fuel assembly payload is 669½ lb (The information in the addendum indicates this value is approximately 646 lb.), including radioactive materials (169 sodium-bonded fuel pins), cropped fuel assembly hardware, and 6CVL. This payload weight is less than the 700 lb evaluated in the SARP;
- The maximum mass of sodium metal included as part of the payload is 1,525 grams, 1,521 grams sealed inside the 6CVL and 4 grams on its exterior surface;
- The shielding evaluation assumes a conservatively high burn-up of 200 MWd/kg heavy metal, which bounds the values used in the *Metal Fuel Test Program in the FFTF*[8];
- The shielding evaluation establishes a worst-case of five years of decay. However, the fuel materials have been decaying and cooling since March 1992 (over 15 years) when FFTF operation ceased;
- The chemical form is metal FFTF reactor fuel. No significant quantity of neutron absorbing or moderating materials (including moisture) is present within the payloads;
- The physical form is solid, encapsulated within stainless steel cladding as a group of FFTF fuel pins or a single, cropped metal fuel assembly (shortened by cutting away the inlet nozzle). The boundary provided by the 6CVL Containment Vessel eliminates the need to evaluate the condition of the cladding;
- The slug density of the sodium-bonded metal fuel material is 15.8 g/cm^3;
- Among chemical, galvanic, or other reactions, only the sodium-water reaction is potentially significant and is precluded, as described in Chapter 1 of the Addendum;
- The decay heat of the proposed payload is limited to 150 watts, which is less than the 1,400 watts evaluated in the SARP;
- The MNOP for the Cask cavity is 6.8 psig, which is less than the 68 psig evaluated in the T-3 SARP; and
- The MNOP for the 6CVL Containment Vessel is 108 psig, which is less than the vessel's design pressure of 800 psig. The hydrostatic test pressure is 1,235 psig.

Findings

The 6CVL is leak tight under ANSI N14.5,[9] and is based on the Chalfant design,[10] used for the Model 9968,[11] Model 9975,[12] and Model 9977 Packages.[13] Conceptually, the 6CVL provides both a canister, and an independent containment vessel, for binary and ternary sodium-bonded metal fuels in the form of individual fuel pins and cropped fuel assemblies. In the former case, the individual fuel pins are contained within the seven compartments of the IPCA. The IPCA is accommodated by the 6CVL, which, in turn, is contained by the T-3 Shipping Cask. In effect, the combination of the T-3 Shipping Cask and the 6CVL provides a nested, double containment boundary for the proposed new contents, i.e., the outer containment boundary is provided by the T-3 Shipping Cask, while the independent containment boundary provided by the 6CVL is supplemental. Water in-leakage past the first boundary does not react with the sodium-bonded contents located within the 6CVL. Appendix 3.5.5 of the Addendum discusses reaction of water with residual sodium found on the 6CVL exterior. A decay heat of 150 watts is the limit per shipment.

Based on the review of the information, statements, and representations in the Addendum, the Staff has concluded that the General Information Chapter of the Addendum has been adequately described and meets the requirements of 10 CFR 71.

Conditions of Approval
The list of drawings, defining the 6CVL, will be included in Revision 13 of the CoC. These drawing are summarized in the following table (adapted from Table 1.7 in the Addendum):

Drawing Number	Title	Revision
R-R1-A-00035	T-3/6CVL Independent Fuel Canister Containment Vessel Assembly	3
R-R3-A-00028	T-3/6CVL Independent Fuel Canister 6CVL Vessel Weldment	2
R-R4-A-00040	T-3/6CVL Independent Fuel Canister Dual Handling Socket Details	3
R-R4-A-00041	T-3/6CVL Independent Fuel Canister Cone Seal Plug and Nut Details	3
R-R4-A-00042	T-3/6CVL Independent Fuel Canister Lower Support Pedestal Details	1
R-R4-A-00043	T-3/6CVL Independent Fuel Canister Weldment Parts Details	2

The following conditions that apply to the new contents will be added in Revision 13:

- A maximum of 80 sodium-bonded metal fuel pins can be placed within the IPCA.
- A single cropped metal fuel assembly contains up to 169 sodium-bonded metal fuel pins is placed inside the 6CVL Independent Fuel Canister Containment Vessel Assembly.
- The maximum mass of sodium metal included as part of the payload is 1,525grams, 1,521 grams sealed inside the 6CVL and 4 grams on its exterior surface.
- The Criticality Safety Index is 0 for shipment of contents addressed by the addendum.

Chapter 2: Structural Evaluation

This section covers the assessment of the Structural Evaluation information provided in Chapter 2 of the Addendum.[1]

Findings
The Addendum contains adequate calculations and supporting information to demonstrate that the 6CVL is needed, and is able to provide additional structural margin to the T-3 Cask for the shipment of the special contents. The Addendum demonstrates that the T-3 Cask, containing the 6CVL, meets all 10 CFR 71 requirements concerning structural design, material, fabrication, inspection, and testing.

The Hypothetical Accident Conditions (HAC) impact analyses addressed two questions regarding the T-3 Cask design: (1) some impact-limiter-attachment bolts may fail in a 30-ft end drop; and (2) the cask cylinder may deform plastically in the mid-span region during a 30-ft side drop. These analyses led the applicant to:

1. remove the impact limiters from the analysis model for the HAC fire; and
2. use plastic analysis for all HAC drop evaluations.

Decision #1 is a conservative one. As described in the following chapter — Chapter 3 — of this TRR, the containment O-rings will survive the fire with comfortable margin even under the worst condition of losing the impact limiter. Decision #2, however, is not consistent with Regulatory Guide (RG) 7.6,[14] which requires an elastic analysis of the containment vessel. Compared to a plastic analysis, an elastic analysis imposes in effect a smaller amount of impact energy to be absorbed by the containment. Thus, an elastic analysis provides a greater structural margin of safety for the containment. For a 30-ft side drop of the T-3 Cask, the Addendum demonstrated that the RG 7.6 criteria cannot be met in the mid-span region of the cask and the 6CVL due to excessive bending generated by the drop. Therefore, a plastic analysis was used to obtain an indication of the available structural margin. The Addendum estimated the worst resulting true plastic strain in the 6CVL to be 2%, which is considerably larger than the yield strain of 0.2% for the elastic analysis, but is comfortably smaller than the true strain of 14%, corresponding to 90% of the ultimate strength of the 6CVL material, 304L stainless steel.

The Addendum, however, did not demonstrate that the RG 7.6 criteria can be met in all other areas and loading conditions. In particular, the Addendum neglected to address the 6CVL closure, which, based on the Staff's estimate, will remain elastic for all HAC drops. As a consequence the Staff performed independent analysis to address these issues.

In the case of a side drop, the Staff found that the closure region is well protected by the 6CVL vessel support rings from a collision with the cask cavity wall. Thus, the closure should remain elastic in all side drops. The same conclusion also holds for all bottom-down drops, due to the absence of significant impact loads. Only in the top-down drops, would the 6CVL closure experience a significant impact load, which is generated by the total mass of the contents and/or the 6CVL body. The Staff estimated that the threaded areas of the cone-seal nut and the 6CVL wall have the most critical stress conditions. Using the total contents weight of 405 lb and the maximum impact g-load of 88 g, the threaded area can be shown to have a shear stress of about 3,060 psi, which is less than one-half of the yield strength (17,500 psi at 400°F) of the 6CVL material, 304L SS. Therefore, it is prudent to state that the 6CVL closure remains elastic and thus can maintain containment for all HAC drops.

Therefore, based on the review of the statements and representations in the Addendum, the Staff has concluded:

1. The 6CVL is needed for the shipment of the special contents, and

2. The 6CVL has been adequately described and demonstrated to meet the requirements of 10 CFR 71.

Conditions of Approval

The Staff has concluded that no additional structurally-related conditions of approval need to be added to the existing CoC for approval of this request.

Chapter 3: Thermal Evaluation

This section covers the assessment of the Thermal Evaluation information provided in Chapter 3 of the Addendum.

Findings

The packaging described in the Addendum adequately complies with the requirements of 10 CFR 71. The Staff has determined that the double containment system design, consisting of the existing T-3 cask and the 6CVL supplemental containment described in the Addendum, will significantly improve the thermal margin of safety of the T-3 shipping package. This determination is based on the following considerations:

1. With the maximum 150 W decay heat from the proposed payload of sodium-bonded metal fuels bins, both calculations from the applicant and from the Staff indicate that under normal conditions of transport (NCT), the maximum temperature of the 6CVL, the T-3 Cask inner shell (the T-3 containment vessel) and other structural components are below the temperature limit of 400°F, which is set by the applicant based on ASME B&PV Code, Section III, Subsection NB and Section II, Part D.
2. For Hypothetical Accident Conditions (HAC), both analyses by the applicant and by the Staff show that the maximum temperature of the 6CVL is close to the temperature limit of 400°F while the maximum temperature of the cask inner shell is above 400°F but below temperatures where creep rupture of the components would be a concern. For the 6CVL and inner cask shell, the combined thermal and structural loading results in stress intensities that are less than the ASME design stress intensity limits, with material properties evaluated at corresponding elevated temperatures.
3. In order to prevent a catastrophic accident from water entering the 6CVL, a large margin of safety on the 6CVL O-rings must exist. From the analyses provided by the applicant and by the Staff, the maximum temperatures of the Viton™ GLT O-rings that form the containment boundaries, during NCT, are well below their operating temperature limit (400°F) specified by the manufacturer. Also during HAC, the revised T-3 double containment design has demonstrated an adequate thermal margin of safety. The peak temperature of the 6CVL O-rings is 278°F, well below the operating temperature limit, although the O-rings in the inner cask shell remain marginal. During the HAC event, temperatures of the Cask O-rings are momentarily above the operational temperature limit of 400°F, but well below the short duration temperature limit of 528°F.
4. In the case of changing the cover gas from nitrogen (N_2) to argon (Ar) inside and outside the 6CVL, about a 5% temperature decrease in 6CVL O-rings occurs during the HAC event. This change will not significantly affect the overall thermal margin of safety of the T-3 packaging.
5. The MNOP of 6CVL is 108 psig, which is considerably less than the design pressure of 800 psig which has been established in Chapter 2 of the Addendum and for a similar containment vessel design of the certified 9975 packaging. The pressure inside the T-3 cavity could go up to 1,344 psi from the reaction of sodium and water. However, this has been accounted for in the previously approved T-3 SARP, and is not a concern.

Therefore, based on the review of the information, statements, and representations in the Addendum, the Staff has concluded that the thermal design of the T-3 Shipping Cask, containing the 6CVL containment vessel, as described in the Addendum, has been adequately described to meet the requirements of 10 CFR 71.

Conditions of Approval

The Staff has shown by analysis that, during the HAC fire, the fire shield, installed on the exterior surface of the T-3 cask, has a significant effect on the temperatures of the containment O-rings of the 6CVL and the cask inner shell. The visual inspections in Section 7.1.2, 7.2.3 and 8.2.2 of the SARP shall include a visual inspection of the fire shield for indications of possible damage. (See also, the *Conditions of Approval* section for Chapters 7 and 8, below.)

Chapter 4: Containment Evaluation

This section covers the assessment of the Containment Evaluation information provided in Chapter 4 of the Addendum.

Findings

The Addendum describes the addition of a supplemental canister/containment vessel, i.e., the 6CVL Independent Fuel Canister Containment Vessel Assembly, or 6CVL, to the existing T-3 Shipping Cask cavity. This additional canister/containment vessel meets the provisions outlined in the Nuclear Regulatory Commission's (NRC), Interim Staff Guidance (ISG) document, ISG-1, and it precludes the in-leakage of water into the new canister/containment cavity.

The 6CVL is a stainless steel (SS) pressure vessel designed, analyzed, and fabricated in accordance with the American Society of Mechanical Engineers Boiler and Pressure Vessel (ASME B&PV) Code, Section III, Subsection NB.

The 6CVL closure seal incorporates two concentric fluoro-elastomeric O-rings that fit into circumferential grooves machined into the cone-seal plug. The inner O-ring serves as part of the supplemental containment boundary. The location of the outer O-ring forms a small external volume to facilitate leak-rate testing of the inner O-ring. The outer O-ring is not part of the supplemental containment boundary, but it does present an additional and significant barrier to the release of package contents.

Conditions of Approval

Based on the review of the statements and representations in the Addendum, the Staff has concluded that the package design with the 6CVL and the proposed new contents has been adequately described and meets the requirements of 10 CFR 71. The Staff has also concluded that no additional containment-related conditions of approval need to be added to the existing CoC for the approval of this request.

Chapter 5: Shielding Evaluation

This section covers the assessment of the Shielding Evaluation information provided in Chapter 5 of the Addendum.

Findings

The Addendum presents details of the neutron and gamma source terms and the shielding models used to calculate bounding dose rates. The source terms used in the calculations were generated using a conservative cooling time of 5 years and a burnup of 200 MWd/kg. This source term was shown to bound the individual fuel types and quantities that would constitute the actual payload.

The shielding model had a consolidated fuel cylinder with a lower density than that used to determine the cylinder dimensions. This represents a conservatism of concentrating the source in a small volume, while at the same time reducing the self-shielding provided by the source material. The lower sub-critical multiplication that arises from the lower density material was compensated for by applying a sub-critical multiplication factor based on the highest k_{eff} obtained in the criticality evaluations to the neutron dose rates. Credit was also not taken for the hardware in the source material though the gamma source terms were calculated with the hardware being included.

The Staff has reviewed these details, performed independent evaluations where needed, and concluded that the calculations based on these models generate bounding dose rates that meet external radiation requirements of 10 CFR 71.

Conditions of Approval

Based on the review of the statements and representations in the Addendum, the Staff has concluded that the package design with the proposed MFF and IFR fuel payloads has been adequately described and evaluated to meet the external radiation requirements of 10 CFR 71. The Staff has, therefore, concluded that no additional shielding-related conditions of approval need to be added to the existing CoC for the approval of this request.

Chapter 6: Criticality Evaluation

This section covers the assessment of the Criticality Evaluation information provided in Chapter 6 of the Addendum.

Findings

This section evaluates shipment of sodium-bonded metal fuel pins in the T-3 Cask. The payloads consist of a cropped 169-pin assembly, or individual pins consisting of either unirradiated spares or from one or more dismantled assemblies packaged in a 6CVL Independent Fuel Canister Containment Vessel Assembly. The payloads of interest are the MFF (binary metal fuel) and IFR-1 (binary and ternary metal fuel) series test assemblies, or loose pins from these assemblies. Two sodium-bonded metal fuel payloads are addressed in this evaluation:

1. An entire 169-binary fuel pin assembly or 169 loose binary fuel pins with a uranium enrichment less than or equal to 34-wt% ^{235}U; and

2. 169 loose ternary fuel pins with 20-wt% Pu (5.8-wt% ^{240}Pu), 70-wt% U (4.5-wt% ^{235}U), and 10-wt% Zr or with 8-wt% Pu (5.8-wt% ^{240}Pu), 82-wt% U (17.5 wt% ^{235}U), and 10-wt% Zr.

These configurations conservatively bound the payloads identified in Chapter 1 of the Addendum. A mixed payload of up to a total of 169 ternary and binary fuel pins is bounded by the results for 169 binary pins or 169 ternary pins.

This evaluation does not take credit for the integrity of the fuel or for any geometry control for the fissile material that may be provided by the fuel assembly hardware, fuel pins, or IPCA. The evaluation addresses water in-leakage into the Cask as required by 10 CFR 71.55(b). However, the 6CVL has been designed and constructed specifically to supplement the containment boundary provided by the T-3 Cask inner shell. The 6CVL Containment Vessel is a leak-tight design and prevents water in leakage under HAC. Therefore, it is justified to assume dry conditions inside the 6CVL Containment Vessel.

Either a cropped 169-fuel pin assembly, or an IPCA housing loose pins, is placed inside the 6CVL Containment Vessel. But the fissile/fissionable fuel material is conservatively configured as a sphere. This is the most reactive configuration consistent with a possible damaged condition and the chemical and physical form of the material. This configuration is extremely conservative and would not be expected to occur under NCT or HAC. However, considering the fact that no credit is taken for geometry control provided by the 6CVL or the IPCA, this configuration conservatively meets the requirements of 10 CFR 71.55(b) and 71.55(e)(1). The criticality analyses were performed for dry conditions inside the 6CVL Containment Vessel, with and without a stainless steel reflector.

Single Package Evaluation

The k_{eff} for a single T-3 Cask with a full MFF binary assembly with dry conditions inside the cask and 6CVL is only 0.2842. The maximum k_{eff} of 0.7867 corresponds to 169 IFR-1 ternary fuel pins (cask cavity flooded, and 6CVL cavity filled with steel). This shows that the sphere model is very conservative and still demonstrates a substantial subcritical margin, because the maximum k_{eff} is well below the k-safe limit 0.9100.

All k_{eff} values demonstrate that all payload configurations meet the NCT and HAC criticality requirements of 10 CFR 71.55(b), (d), and (e) when the 6CVL is dry.

Evaluation of T-3 Cask Arrays under NCT and HAC Scenarios

Under the NCT scenarios, an infinite array of T-3 Casks loaded with any type of bounding fuel configurations is shown to be subcritical and has an adequate subcritical margin with a maximum k_{eff} value of 0.8186.

The NCT and HAC array models used for the analyses are identical. This is justified because there is essentially no deformation of the Cask under the regulatory accident scenarios.

An infinite array model is also used for the HAC scenarios. Various interspersed moderation between casks in the array are evaluated. The maximum k_{eff} value of 0.8188 corresponds to water density of 0.001 g/cc in the interspersed region. Optimum interspersed moderation is essentially no moderation, because water basically acts like an isolator. Therefore the maximum k_{eff} for the NCT and HAC arrays are identical (within one standard deviation).

Benchmark Evaluations

The Addendum uses the same code (MCNP5) and cross section library (0.60c set) to determine the bias values from the selected benchmark experiments, and to calculate the k_{eff} values for the evaluation.

The experimental benchmarks are taken from NEA/NSC/DOC(95)03, *International Handbook of Evaluated Criticality Safety Benchmark Experiments*.[15] However, there are no suitable benchmark experiments for the FFTF fuel. Several uranium and plutonium benchmark experiments are chosen which have similar spectra as the FFTF content. A *minimum subcritical margin* (MSM) of 0.05 is used in determining the limiting subcritical value. An additional margin of 0.02 is added as the *areas of applicability margin* (AOA). No statistical techniques are used for estimating the bias value. But the overall method is conservative and the limiting subcritical value (k-safe) of 0.91 is acceptable.

Based on the above discussion, the Staff has concluded that the T-3 Package with the FFTF assemblies can be shipped with a CSI of 0.

Conditions of Approval

Based on the review of the statements and representations in the Addendum, the Staff notes that criticality safety analyses are based on a very conservative model. The Staff also notes that analyses demonstrated an adequate margin of safety for this package. Therefore, the Staff has concluded that the T-3 package design with the FFTF payload meets the criticality safety requirements of 10 CFR 71, and that no additional criticality-related conditions of approval need to be added to the existing CoC for the approval of this request.

Chapter 7: Operating Procedures Review

This section covers the assessment of the Operating Procedures information provided in Chapter 7 of the Addendum.

Findings

Based on the review of the statements and representations in the Addendum, the Staff has concluded that, for the most part, the Operating Procedures have been adequately described and meets the requirements of 10 CFR 71. The one exception is that the Operating Procedures Chapter did not include a specific requirement to purge the T-3 Cask cavity "...with high purity nitrogen gas...," as is noted in Section 1.2.2.5 of the Addendum. When the addendum was first submitted for review, operating plans for the facility were to change from argon gas to nitrogen gas. Based on this operation plan for the facility, the addendum addressed the use of nitrogen gas. Towards the end to the review process, an operational decision was made to delay the conversion from argon gas to nitrogen gas for an undetermined period of time. Based on this decision, the addendum was rewritten to address a purge of the T-3 Cask cavity with high purity nitrogen gas. EM-60 staff conducted a confirmatory analysis and determined that either argon or nitrogen gas could be used in the T-3. Because the facility is now using argon gas, argon gas will be used in the T-3. Therefore the error Chapter 7 of not addressing the action stated in Section 1.2.2.5 is not a safety issue or compliance issue and does not need to be corrected for this Revision of the CoC

Conditions of Approval
As stated in Section 3, the visual inspections in Section 7.1.2, 7.2.3 and 8.2.2 of the SARP shall include a visual inspection of the fire shield for indications of possible damage.

Chapter 8: Acceptance Tests and Maintenance Program Review

This section covers the assessment of the Acceptance Tests and Maintenance Program information provided in Chapter 8 of the Addendum.

Findings
Based on the review of the statements and representations in the Addendum, the Staff has concluded that the Acceptance Tests and Maintenance Program for the 6CVL has been adequately described and meets the requirements of 10 CFR 71. The Acceptance Tests and Maintenance Program for the T-3 Cask are addressed in the SARP.

Conditions of Approval
The requirements specified in Chapter 8 are incorporated, in their entirety into the CoC. As stated in Section 3, the visual inspections in Section 7.1.2, 7.2.3 and 8.2.2 of the SARP shall include a visual inspection of the fire shield for indications of possible damage as a Condition of Approval.

Chapter 9: Quality Assurance Review

This section covers the assessment of the Quality Assurance information provided in Chapter 9 of the Addendum.

Findings
Chapter 9 of the Addendum supplements Revision 6 of the Model T-3 SAR. Because the existing T-3 SAR does not contain a Chapter 9, the current Chapter 9 applies only to the 6CVL Independent Fuel Canister Containment Vessel Assembly.

Based on a review of the statements and representations in the Addendum, the Staff concludes that the Quality Assurance program has been adequately described and meets the quality assurance requirements of Subpart H of 10 CFR 71. Package-specific requirements are adequate to assure the 6CVL package is designed, fabricated, assembled, tested, used, maintained, modified, and repaired in a manner consistent with its evaluation.

Conditions of Approval
Based on the review of the statements and representations in the Addendum, the Staff has concluded that the quality assurance program for the 6CVL has been adequately described to meet the requirements of 10 CFR 71. The Staff agrees, and therefore concludes, that no additional quality assurance-related conditions of approval need to be added to the existing CoC for the approval of this request.

References

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[2] *U.S. Department of Energy Certificate of Compliance (CoC), USA/9132/B (M) F (DOE), Revision 12,* January 2007.

[3] *Consolidated Safety Analysis Report for the T-3 Spent Fuel Shipping Cask,* WHC-1990, Revision 6a, Westinghouse Hanford Company, Richland, Washington, August, 1990.

[4] *ASME Boiler and Pressure Vessel Code Section III, "Rules for Construction of Nuclear Facility Components,"* Subsection NB, American Society of Mechanical Engineers, New York, NY (2004).

[5] *Damaged Fuel,* Interim Staff Guidance-1, Revision 1, Spent Fuel Projects Office, Nuclear Regulatory Commission, October 25, 2002.

[6] 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.

[7] *IAEA Safety Requirements No. TS-R-1, Regulation for Safety Transport of Radioactive Material,* April 2005

[8] *Pitner, A.L. and Baker, R.B., Metal Fuel Test Program in the FFTF, Journal of Nuclear Materials, Volume 204, pp. 124-130* (1993).

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

[10] *Chalfant, Jr., Gordon G, Conical O-ring Seal, United States Patent 4465201* (August 14, 1984).

[11] *Safety Analysis Report for Packaging Model 9968, WSRC-DPSPU 83-124-1, Rev. 2,* February 1992

[12] *Safety Analysis Report for Packaging Model 9975, WSRC-SA-2002-00008 Rev. 1.* April 2005

[13] *Safety Analysis Report for Packaging Model 9977, S-SARP-G-00001, Rev. 0,* May 2006

[14] *United States Nuclear Regulatory Commission Regulatory Guide 7.6, Design Criteria for The Structural Analysis of Shipping Cask Containment Vessels, Rev. 1* (March 1978).

[15] *NEA/NSC/DOC(95)03, International Handbook of Evaluated Criticality Safety Benchmark Experiments, Nuclear Energy Agency, Organization for Economic Co-Operation and Development* (September 2005 Edition).