SAFETY EVALUATION REPORT

Docket No. 71-9792
Model No. Model D1G Core Basket Thermal Shield Shipping and Storage Container
Certificate of Compliance No. 9792
Revision No. 11

SUMMARY

By letter dated October 13, 2020 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML20304A395), as supplemented on April 26, 2021 (ADAMS Accession No. ML21140A092), the Department of Energy, Division of Naval Reactors submitted an amendment request to revise the certificate of compliance for the Model No. D1G Core Basket Thermal Shield Shipping and Storage Container (Model 1 container) package. The applicant submitted a revised Safety Analysis Report for Packaging (SARP). Nuclear Regulatory Commission staff (the staff) reviewed the application using the guidance in NUREG-2216, "Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material." Based on the statements and representations in the application, as supplemented, the staff finds that these changes do not affect the ability of the package to meet the requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 71.

1.0 GENERAL INFORMATION

The applicant designed the Model 1 container as a right circular cylinder approximately 115 inches in diameter and 209 inches long including the impact limiter assembly with a weight of up to 185 tons. The applicant provided access for loading using a removable closure head. The container design, which consisted of the cylindrical side walls and the bottom end, utilized a three-layer construction with a steel inner vessel approximately eight inches thick covered with approximately nine inches of reinforced concrete that is encased by a 3/8-inch thick stainless steel outer shell. The applicant secured the core barrel assembly in place inside the container by a steel preload ring that is bolted to the inner vessel with 72 high strength bolts.

A steel closure head, which is fastened to the inner vessel with 72 high strength bolts, provided closure of the containment vessel. The applicant welded a steel closure ring over the bolts to provide containment. The applicant then welded a steel inner impact limiter to the top end of the closure ring before bolting a wood outer impact limiter to the top plate of the container outer shell. The applicant designed the shipping container to be transported with its axis horizontal supported by a shipping skid.

Based on a review of the statements and representations in the application, the staff finds that the contents have been adequately described to meet the requirements of 10 CFR Part 71.

2.0 STRUCTURAL

2.1 General

The staff reviewed the application to verify that shipping the D2W core barrel assembly in the Model 1 container meets the structural performance requirements of 10 CFR Part 71. The applicant originally designed the Model 1 container as a single-use container for transportation and disposal of only D1G core basket assemblies. The applicant later redesigned the Model 1 container to support the non-exclusive use shipment of other core barrel assemblies. Subsequently, the applicant built two versions of the Model 1 container: modified and redesigned containers.

The applicant recently identified a need to use the redesigned Model 1 container to ship the D2W core barrel assembly. As a result, the applicant submitted an application that contains additional information for the D2W core barrel assembly in the redesigned Model 1 container (herein referred to as the D2W package) to demonstrate the structural design adequacy of the D2W package under both normal conditions of transport (NCT) and hypothetical accident conditions (HAC) as required by 10 CFR Part 71.

2.1.1 Source Specification

The proposed package consisted of three principal structures: the Model 1 container, the D2W core barrel assembly, and energy absorbers (i.e., impact limiters). The applicant provided both the shipping configuration of the package in SARP Figure A.1.1-3 of Chapter A1, and detailed descriptions of the package (i.e., weight, dimensions, material types, etc.) in SARP Section A.1.2 and SARP Section A.2.1. In addition, the applicant provided the general assembly drawings of the package in SARP Appendix A.1.3.3. The drawings identified the major important-to-safety components of the package as well as detailed information to demonstrate compliance with 10 CFR 71.33(a) and 71.107(a). After reviewing the structural descriptions and drawings for completeness and accuracy, the staff finds that the package geometry, materials, dimensions, and components as well as drawing notes and fabrication details are adequately described.

2.1.2 Design Criteria

The applicant used similar design criteria to evaluate the D2W package as the design criteria used for previous evaluations of the Model 1 container as documented in SARP Section 2.1.2, Revision 0. For the NCT evaluations, the applicant stated that the package must remain elastic although minor deformation is allowed. For the HAC evaluations, the applicant stated that material deformation is permitted provided the deformation does not affect regulatory compliance. The applicant evaluated the D2W package responses under NCT and HAC using closed-form calculations. Using closed-form calculations allowed the applicant to compare applicable engineering stress limits (yield or ultimate strength). The applicant used load combinations for evaluating the package under NCT and HAC based on the guidelines provided in Regulatory Guide (RG) 7.8, Revision 1, "Load Combinations for the Structural Analysis of Shipping Casks for Radioactive Material," March 1989. SARP Table A.2.1-1 summarized the load combinations that are provided in RG 7.8. Based on a review of the design criteria presented in SARP Section A.2.1.2, the staff finds the structural design criteria for the D2W package are acceptable because the design of the D2W package is similar to the D1G package design (i.e., load, dimensions, configurations, materials, etc.), the weight of the D2W package is less than the weight of the D1G package, and the structural design criteria, analyses and designs of the D1G package were previously reviewed and accepted by the staff.

2.1.3 Weights and Centers of Gravity

The applicant provided nominal weights and center of gravity (CG) locations of the D2W package components in SARP Table A.2.1-2 and SARP Figure A.2.1-1. The applicant used these weights and CG locations in the structural evaluations to demonstrate that the 10 CFR Part 71 NCT and HAC requirements are satisfied. The staff reviewed the information and finds that the applicant adequately described the weights and adequately determined the CG locations.

2.2 Fabrication and Examination

The applicant fabricated and examined the D2W package components in accordance with the engineering design drawings in SARP Chapters A1. In addition, the applicant fabricated and examined those components in accordance with the Naval Nuclear Propulsion Program standards, as discussed in the SARP, Revision 0, which the staff previously reviewed and accepted. After reviewing the statements and drawings, the staff finds that the applicant provided adequate information to describe the fabrication and examination requirements.

2.3 General Requirements for All Packages

2.3.1 Minimum Packaging Size

Because the smallest overall dimension of the D2W package is approximately 114 inches, which is larger than the minimum regulatory requirement of 4.0 inches, the staff finds that the D2W package meets the regulatory requirement of 10 CFR 71.43(a).

2.3.2 Tamper-Indicating Features

Because the D2W package is a welded structure, the applicant asserted that intact seal welds provide evidence that the package has not been opened. The staff finds that the D2W package meets the regulatory requirements of 10 CFR 71.43(b).

2.3.3 Positive Closures

The applicant fastened the closure head to the inner vessel with 72 closure head bolts and welded a closure ring to the Model 1 container. The applicant stated that these design aspects maintained positive closure and prevented inadvertent opening of the package. The staff finds that the D2W package meets the regulatory requirements of 10 CFR 71.43(c).

2.4 Lifting and Tie-Down Standards for All Packages

The applicant stated that the D2W package meets the 10 CFR 71.45(a) and 71.45(b) requirements for lifting devices and tie-down standards respectively. The staff determined that the D2W package lifting and tie-down standards are identical to those previously reviewed by the staff for the D1G package in the SARP, Revision 0. Because the lifting and tie down standards were previously accepted, the staff finds that the D2W package meets the regulatory requirements of 10 CFR 71.45(a) and 71.45(b).

2.5 Normal Conditions of Transport

The applicant evaluated the D2W package under NCT as required by 10 CFR 71.71. The applicant analyzed the D2W package using the same analytical methodologies used for the D1G package in the SARP, Revision 0. The applicant used the closed form solutions, the methodologies developed through the Naval Nuclear Propulsion Program, and, if applicable, the results of the previous structural analyses for the D1G package to demonstrate compliance with the 10 CFR 71.71 NCT regulatory requirements for the D2W package.

2.5.1 Heat

The applicant performed thermal evaluations of the D2W package to demonstrate structural design adequacy of the package for the temperatures specified in 10 CFR 71.71(c)(1). The applicant provided detailed thermal evaluations and their results in SARP Chapter A3. The applicant briefly summarized the thermal analysis in SARP Section A.2.6.1:

Summary of Pressure and Temperatures: The applicant calculated the maximum NCT temperature as well as the maximum NCT operating pressure in SARP Sections A.3.1 and A.3.3 respectively. The results of the evaluations showed that the maximum temperature will not damage the D2W package components, and the maximum pressure will not cause the loss of radioactive material.

Stress Calculations and Comparison with Allowable Stresses: SARP Table A.2.12.2-1 in Appendix A.2.12.2 summarized the calculated values for stress and displacement as well as compared these values with the allowable limits. The applicant concluded that the values in the D2W package structural components are acceptable under combined pressure and thermal loadings because the calculated values are lower than the allowable limits. After reviewing the applicant's evaluations, the staff finds that the D2W package meets the regulatory 10 CFR 71.71(c)(1) requirements.

2.5.2 Cold

In accordance with 10 CFR Part 71.71(c)(2), which requires that the package be subjected to a temperature of -40°F in still air and shade, the applicant performed a thermal evaluation for the D2W package under the cold NCT condition in SARP Chapter A3. In addition, the applicant analyzed the effects of cold on the package in SARP Section A.2.6.2. Because there would be approximately 3.63 gallons of residual water remaining in the Model 1 container, the applicant identified that water freezing in the Model 1 container could cause stresses in D2W components during shipment due to expansion of the freezing water.

SARP Appendix A.2.12.6 provided brittle fracture evaluations for the Model 1 container components under NCT and HAC that included the effects due to freezing residual water. The applicant performed the fracture evaluations based on fracture mechanics concepts. The applicant also utilized the criteria established in RG 7.12, "Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Wall Thickness Greater than 4 Inches (0.1 m) but not Exceeding 12 Inches (0.3 m)", June 1991.

The applicant identified that the preload ring, core barrel flange and w-bracket components were susceptible to brittle fracture. Consequently, the applicant evaluated these components for brittle fracture in SARP Sections A.2.12.6.3.1, A.2.12.6.3.2, and A.2.12.6.3.3 in Appendix A.2.12.6 respectively. Because the applicant required package shipments occur only when ambient temperatures are greater than or equal to 10ºF, the applicant performed the brittle fracture evaluations at the 10ºF lowest service temperature established for the Model 1 container.

After reviewing the application, the staff determined that brittle fracture does not occur for the preload ring and w-bracket components, but that the core barrel flange component has the potential for brittle fracture. However, as discussed in SARP Section A.2.6.8, the stresses experienced in the core barrel flange under the effects of fracture during NCT are less than the ultimate tensile strength of the material. As a result, the staff concluded that no significant stresses develop due to thermal contraction. Therefore, the staff finds that the D2W package satisfies the regulatory 10 CFR 71.71(c)(2) requirements.

2.5.3 Reduced External Pressure

In accordance with 10 CFR Part 71.71(c)(3), the applicant evaluated the package under a reduced external pressure of 3.5 psia. As shown in SARP Table A.2.6-1, the applicant calculated a maximum D2W package internal pressure during NCT of 58.8 psia. Therefore, a reduced pressure of 3.5 psia resulted in a differential pressure of 58.8 - 3.5 = 55.3 psig. The applicant demonstrated in SARP Section A.2.6.5 that the limiting closure head bolt stress remains below the material yield strength at a gage pressure of 66.2 psig. Therefore, the applicant concluded that the stresses in the structural components of the D2W package under a reduced external pressure of 3.5 psia are acceptable. The staff reviewed the applicant's evaluations in SARP Section A.2.6.5 and concurs that the effects of a reduced external pressure of 3.5 psia are negligible. The staff finds that the D2W package meets the 10 CFR 71.71(c)(3) regulatory requirements.

2.5.4 Increased External Pressure

In accordance with 10 CFR Part 71.71(c)(3), the applicant evaluated the package to an external pressure of 20 psia. The applicant stated that the effect of an external pressure of 20 psia is considered negligible for the D2W package. The applicant based this conclusion on the NCT structural analysis results presented in Section 2.6.3.2 of the SARP, Revision 0 which previously demonstrated the Model 1 container structural integrity for an increased external pressure of 20 psia. Because the Model 1 container and the D2W package are very similar, the staff finds that the D2W package meets the 10 CFR 71.71(c)(4) regulatory requirements.

2.5.5 Vibration

The applicant stated that the effects of vibration are considered negligible for the D2W package. After calculating the natural frequency of the D2W core barrel assembly, the applicant found that the frequency, which was approximately 56.8 Hertz, significantly exceeded the vibration frequencies expected during transportation which are approximately 2.5 to 7.5 Hertz. After reviewing the frequency calculation, the staff concluded that, because the package's natural frequency is greater than the forcing frequency, there will not be significant dynamic amplification of vibrations. As a result, the staff determined that the possibility of resonance and subsequent elevated stress conditions is not credible. In addition, the extensive service history of the D1G package, which is a similar package to the D2W package, supported this finding because the D1G package has experienced no significant vibration induced issues. Therefore, the staff finds that the regulatory requirements of 10 CFR 71.71(c)(5) for normal vibration during transportation are met.

2.5.6 Water Spray

The 10 CFR Part 71.71(c)(6) regulation, which is primarily intended for packaging fabricated from material that either absorbs water or is softened by water, required the applicant to subject the package to a water spray test that simulates rainfall of approximately two inches/hour for at least one hour. Because the Model 1 container is a welded structure, the applicant stated that the water spray test has no adverse effect on the package. After reviewing the application, the staff determined that this rationale is acceptable. Therefore, the staff finds that the D2W package satisfies the 10 CFR 71.71(c)(6) regulatory requirements.

2.5.7 NCT Free Drop

The applicant evaluated the D2W package against the 10 CFR 71.71 free drop requirements. The applicant only considered a side drop orientation from a height of one foot onto a flat, essentially unyielding horizontal surface for the analysis. Because the D2W package is shipped in the horizontal orientation, the applicant considered only a side drop orientation from a height of one foot drop to be credible and did not evaluate end drop orientations.

The applicant based the D2W package side drop analysis on the NCT results for the Model 1 container free drop analysis in the SARP, Revision 0. The applicant determined that the D2W package deformations and stresses due to the side drop are bounded by the values calculated from the D1G Model 1 container side drop because the maximum weight of the D2W package is less than the maximum weight of the D1G package.

SARP Figure A.2.12.6-3 in Appendix A.2.12.2 showed that a portion of the core barrel can move approximately 1.99 inches towards the bottom of the inner vessel due to brittle fracture. However, the applicant bounded this movement by assuming a core barrel movement of 2.14 inches in the shielding model in SARP Chapter A5. Therefore, as shown in SARP Table A.5.1-1, the calculated external radiation levels of the package following this reconfiguration remained below the allowable 10 CFR 71 limits. After reviewing the analysis results, the staff finds that the D2W package meets the 10 CFR 71.71(c)(7) regulatory requirements.

2.5.8 Corner Drop

The applicant stated that the 10 CFR 71.71(c)(8) requirement is not applicable to the D2W package because 10 CFR 71.71(c)(8) requires this test for rectangular fissile material packages not exceeding 110 lbs. and cylindrical fissile material packages not exceeding 220 lbs. as well as packages fabricated from either fiberboard or wood. Since the D2W package is an all metal cylindrical package that exceeds 220 lbs., the staff finds that the 10 CFR 71.71(c)(8) regulatory requirement is not applicable to the D2W package.

2.5.9 Compression

The applicant asserted that the 10 CFR 71.71(c)(9) regulatory requirement is not applicable to the D2W package because this test is only required for a package weighing up to 11,000 lbs. Because the weight of the D2W package exceeds 11,000 lbs., the applicant stated that a compression test is not required. The staff finds that the 10 CFR 71.71(c)(9) compression test is not applicable to the D2W package.

2.5.10 Penetration

Per 10 CFR Part 71.71(c)(10), the applicant evaluated the package for penetration from the impact of the hemispherical end of a vertical steel cylinder 1.25 inches in diameter and with a mass of 13 lb. dropped from a height of 40 inches onto the exposed package surface that is expected to be most vulnerable to puncture. The applicant concluded that the closure head component is the most venerable to puncture. The applicant reached this conclusion because the remaining containment boundary components, as well as the inner vessel, are thicker than the closure head. In addition, both the remaining containment boundary components and the inner vessel are surrounded with concrete as well as an outer wrapper. The applicant calculated a maximum penetration depth of 0.00045 inch from the cylinder impacting the closure head. The applicant concluded that the penetration depth is insignificant and does not affect the effectiveness of the package. After reviewing the calculation, the staff finds that the D2W package satisfies the 10 CFR 71.71(c)(10) regulatory requirements.

2.6 Hypothetical Accident Conditions

The applicant evaluated the D2W package against the 10 CFR 71.73 free drop, crush, puncture, thermal, and water immersion HAC. To demonstrate compliance with the 10 CFR 71.73 HAC regulatory requirements, the applicant analyzed the D2W package using the closed-form solutions which were previously used for the D1G package HAC evaluations in the SARP, Revision 0.

2.6.1 Free Drop

Per 10 CFR 71.73(c)(1), the applicant needed to demonstrate the structural adequacy of the package by evaluating a 30-foot free drop onto a flat, unyielding, horizontal surface in a position for which maximum damage is expected. To determine the orientation that produces the maximum damage, the applicant evaluated the D2W package for impact orientations in which the package strikes the impact surface on its top end, bottom end and side.

The applicant stated that, since the load paths, configurations, and weights of the D2W package and the D1G package are similar, the D1G HAC free drop evaluation results were used as much as possible. Therefore, the applicant evaluated only D2W package components that were either replaced or modified as well as D2W components affected by the replacement or modification of D1G components. The applicant discussed the structural component evaluations for the D2W package in SARP Section A.2.7.1 and Appendices A.2.12.3 through A.2.12.6.

SARP Table A.2.12.3-1 in Appendix A.2.12.3 provided the results of the top end drop analysis. Most calculated values (i.e., stress, strain, force, energy) for the components proved to be less than the allowable values. However, the applicant calculated a shear stress for the tie bolt thread component that is larger than the allowable shear stress. This indicated that the tie bolt thread component would not keep the removal cover in place and allow the cover to shift approximately 0.21 inch. Since the main function of the removal cover is to provide shielding for the package, the applicant accounted for the 0.21-inch shift of the removal cover in the shielding evaluation and provided the results in SARP Chapter A5.

SARP Table A.2.12.4-1 in Appendix A.2.12.4 provided the results of the bottom end drop analysis. The calculated stress values for all components remained below the allowable values except for the core barrel shell. The applicant calculated a core barrel shell axial stress of approximately 27,100 psi which is higher than the core barrel shell material's yield strength of 21,700 psi. However, because this calculated stress is significantly less than the material's ultimate strength of 65,700 psi, the applicant concluded that there will be only minor deformation in the core barrel shell. Therefore, the applicant determined that the core barrel shell will maintain its configuration during HAC.

SARP Table A.2.12.5-1 in Appendix A.2.12.5 provided the side drop analysis results. The calculated stress values for all components remained below the allowable values except for the core barrel flange. The applicant calculated a core barrel flange stress intensity of approximately 88,200 psi which is higher than the core barrel flange material's ultimate strength of 74,700 psi. After evaluating the condition, the applicant concluded that it is a limited condition; the applicant determined that the core barrel assembly will contact the inner vessel and that this support condition change will drastically decrease the stress. The applicant's evaluation also showed that this support condition change will occur before ductile failure of the core barrel flange.

The applicant chose not to provide an explicit D2W package oblique drop analysis. The applicant stated that the Model 1 container is an inherently robust container on which the staff previously concurred using the guidance in effect at that time, therefore, the applicant asserted that an explicit drop analysis will not change the conclusions in the SARP, Revision 0.

The staff reviewed the modeling methodologies, the analytical results, the allowable stress comparisons, and the applicant's technical statements. Based on a review of the information submitted, the staff confirmed the applicant's findings. Therefore, the staff finds that the D2W package satisfies the 10 CFR 71.73(c)(1) regulatory requirements.

2.6.2 Crush

Per 10 CFR Part 71.73(c)(2), if the package has a mass not greater than 1,100 lbs., the applicant needed to perform a dynamic crush test by positioning a specimen on a flat, essentially unyielding horizontal surface and dropping an 1,100 lb. mass from 30 feet onto the specimen in order to inflict maximum damage. However, the applicant stated that the crush test specified in 10 CFR Part 71.73(c)(2) is not required since the D2W package weight exceeds 1,100 lbs. The staff confirmed that the D2W package weighs more than 1,100 lbs. Therefore, the staff finds that the 10 CFR 71.73(c)(2) regulatory requirement is not applicable to the D2W package.

2.6.3 Puncture

The 10 CFR Part 71.73(c)(3) requirements specified that the package undergo a free drop, through a distance of 40 inches in a position for which maximum damage is expected, onto the upper end of a solid, cylindrical, mild steel bar mounted on an essentially unyielding, horizontal surface. The regulations specified that the pin must be 6 inches in diameter, and that it must have a horizontal top with its edge rounded to a radius of not more than 0.25 inch. The regulations also specified the long axis of the bar must be vertical with a length that causes maximum damage to the package, but not less than 8 inches long.

The applicant evaluated the puncture performance of the D2W package using the analytical results of the D1G package provided in Section 5.6 of Appendix 2.10.11 of the SARP, Revision 0. The applicant only considered D2W package components that were replaced or modified versus the D1G package. Among those components, the applicant identified the removal cover as the component most vulnerable to puncture under HAC. The applicant designed the D2W package removal cover with a maximum of 0.241 inches between the core barrel assembly and the closure head. The applicant explained minimizing the distance limited closure head bending when impacting the steel bar, stopped the steel bar from piercing the closure head, and prevented penetration of the containment boundary which allowed the D2W package to meet the 10 CFR 71.73(c)(3) requirement.

After reviewing the evaluations, the staff determined that the D2W package has the necessary structural strength and design adequacy under the 10 CFR 71.73 puncture event and that the evaluations are acceptable. Therefore, the staff finds that the D2W package satisfies the 10 CFR 71.73(c)(3) regulatory requirements.

2.6.4 Thermal

The 10 CFR Part 71.73(c)(4) regulation required that the package be evaluated against an average flame temperature of at least 1,475°F for a period of 30 minutes. The applicant performed thermal evaluations of the D2W package under HAC in SARP Chapter A3. The staff's detailed safety evaluations on the applicant's thermal evaluations are provided in SER Chapter 3. In SARP Section 2.7.4, the applicant briefly summarized the SARP Chapter A3 thermal evaluation results which included the following:

(a) no structural parts melt,
(b) all calculated stresses are less than the allowable stresses,
(c) the fire condition does not affect package safety, and
(d) there is no loss of radioactive material.

The staff reviewed the evaluations presented by the applicant and found them acceptable. The staff performed additional reviews of the applicant's thermal evaluations and provided a detailed safety evaluation in Chapter 3 of this SER. The staff finds that the D2W package satisfies the 10 CFR 71.73(c)(4) regulatory requirements.

2.6.5 Immersion – Fissile Material

The applicant stated that 10 CFR Part 71.73(c)(5) is not applicable. The regulation, which requires that fissile material packages subject to 10 CFR Part 71.55 for which water in-leakage has not been assumed for criticality analysis must be evaluated for immersion under a head of water of at least three feet in the attitude for which maximum leakage is expected. The applicant asserted this because the D2W package does not contain fissile material. The staff reviewed the application and determined the D2W package does not contain fissile material. The staff finds that the 10 CFR 71.73(c)(5) regulatory requirements are not applicable for the D2W package.

2.6.6 Immersion – All Packages

Per 10 CFR Part 71.73(c)(6), the applicant needed to subject a separate, undamaged package to water pressure equivalent to immersion under a head of water of at least 50 feet (equivalent pressure of 21.7 psig) for a period of eight hours. The applicant evaluated the D2W package under 20 psig in SARP Section A.2.6.4, where it demonstrated that the thick-walled containment boundary is not susceptible to buckling or collapse. The applicant asserted that the slight pressure difference of 1.7 psig (21.7 psig - 20 psig = 1.7 psig) does not change the analytical conclusion for 20 psig and the D2W package withstands the external pressure.

The staff reviewed the buckling analysis results and the stress calculations. The staff determined that the D2W package has the necessary structural strength and design adequacy to withstand the immersion accident condition of a head of water of at least 50 feet (equivalent pressure of 21.7 psig). Therefore, the staff finds that the D2W package satisfies the 10 CFR 71.73(c)(6) regulatory requirements.

2.6.7 Deep Water Immersion Test (for Type B package containing more than 10^5 A_2)

The applicant claimed that 10 CFR 71.61, which requires that a Type B package containing more than 10^5 A_2 must be designed so that its undamaged containment system can 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, is not applicable. The applicant stated that the D2W package contains less than 10^5 A_2 as shown in SARP Table A.4.2-2. The staff reviewed the table and determined the statement is acceptable. The staff finds that the 10 CFR 71.61 regulatory requirement is not applicable to the D2W package.

2.7 Accident Conditions for Air Transport of Plutonium

This section is not applicable to the D2W package. The applicant did not seek approval for air transport of plutonium; therefore, the SARP did not address the accidents defined in 10 CFR 71.74.

2.8 Accident Conditions for Fissile Materials for Air Transport

This section is not applicable to the D2W package. The applicant did not seek approval for air transport of fissile materials; therefore, the SARP did not address the accidents defined in 10 CFR 71.55(f).

2.9 Special Form

This section is not applicable to the D2W package. The applicant did not seek approval for transport of special form radioactive materials; therefore, the requirements of 10 CFR 71.75 are not applied.

2.10 Evaluation Findings

Based on the review of the statements and representations in the application, the staff concludes that the structural design has been adequately described and evaluated and that the D2W package has adequate structural integrity to meet the structural requirements of 10 CFR Part 71.

3.0 THERMAL EVALUATION

3.1 Description of Thermal Design

3.1.1 Design Features

The applicant described the Model 1 container as consisting of cylindrical steel side walls, a steel bottom end, a steel removeable closure head with high strength bolts, a steel inner vessel, a reinforced concrete covering, and a steel outer shell. The applicant designed and constructed the Model 1 container to be an all-welded single-use container Type B package in accordance with Naval standards and the SARP drawings. The applicant sealed the containment boundary with multiple weld passes. The applicant planned to secure a D2W core barrel assembly (i.e., the content) inside the Model 1 container using a steel ring that is bolted to the inner vessel by high-strength bolts.

The applicant stated that the package is passively cooled. In addition, the applicant indicated that there are no penetrations within the package, no valves, and that the package is not continuously vented. In the general information and operating procedure SARP chapters, the applicant indicated that many of the analyses, operations, and programs (i.e., testing, maintenance) would follow those previously reviewed and concurred on by the staff.

3.1.2 Content's Decay Heat

The applicant described the radioactive content of the package in the SARP Containment chapter as the activated metal of the core barrel assembly, surfaces contaminated with activated corrosion products, and crud that is within a small quantity of residual water. The applicant stated that the decay heat associated with the content is a fraction of a kW. The applicant also noted that the decay heat determination considered the activation of the content due to the reactor's neutron fluxes. The applicant calculated the content's decay heat using a code that accounts for the creation and depletion of nuclides as the result of neutron absorption and nuclide decay. The applicant discussed these sources in more detail in the SARP shielding chapter.

3.1.3 Summary of Temperatures

The applicant noted in the SARP thermal chapter that the maximum temperature of the accessible surface at hot normal conditions (i.e., 100°F) with no insolation was less than the 122°F regulatory limit for non-exclusive use shipments. The applicant also indicated operational controls would be instituted to ensure that the package would be shipped when ambient temperatures are above the lowest service temperature of 10°F. Staff notes that this is a condition of the CoC.

The applicant demonstrated in the SARP structural and thermal chapters that the package temperatures associated with NCT were within allowable temperatures. Likewise, for HAC, the applicant demonstrated in the SARP structural and thermal chapters that numerical analysis results showed that package components did not reach melting temperatures. Numerical analysis results also showed that stresses, including thermal stresses, within the package were such that containment integrity would be maintained.

3.1.4 Summary of Maximum Pressures

According to the SARP thermal and containment chapters, the calculated pressure during NCT and HAC considered the partial pressure of gases within the container, vapor pressure of the residual water, and potential generation of radiolysis gases from the residual water. The calculations based the pressure on an ambient temperature of 100°F (with insolation) and the maximum decay heat. The SARP structural chapter noted that the stresses associated with the pressures during NCT and HAC were less than those allowed by the package's design.

3.2 Material Properties and Component Specifications

The SARP included values associated with the package material thermal properties, including thermal conductivity, surface emissivity, surface absorptivity, density, and specific heat. The applicant noted that the materials and their thermal properties were essentially the same as those used in previously reviewed applications. The staff reviewed the thermal properties and found them to be reasonable especially since the package temperatures during NCT and HAC were relatively low.

3.3 Thermal Evaluation Under Normal Conditions of Transport

According to the SARP thermal chapter, the thermal calculation for hot conditions assumed a 100°F ambient temperature. The applicant performed a transient thermal analysis that modeled twelve hours of insolation on curved surfaces consistent with 10 CFR 71.71(c), followed by twelve hours with no insolation; the transient calculation continued until inner surfaces reached an asymptotic value. The applicant conservatively applied the content's decay heat as a heat flux boundary condition in a small section of the core barrel where maximum temperatures were expected to occur due to the high thermal resistances associated with that particular axial location. For the thermal analysis, the applicant used a finite element analysis numerical code to model heat transfer in one-dimension for this section of the package. The thermal chapter indicated that both spatial sensitivity and transient sensitivity analyses were performed to ensure proper spatial and temporal resolution. Finally, the thermal chapter stated that the numerical code results were validated by comparing them with hand-calculations results assuming steady-state conditions with and without insolation.

According to the SARP structural chapter, the main components of the packaging demonstrated acceptable performance at a low service temperature of 10°F. The applicant employed administrative controls to ensure the package would be shipped when ambient temperatures are above the low service temperature; as mentioned previously, the applicant incorporated this administrative control as a condition in the CoC.

According to the SARP thermal chapter, the numerical analysis results showed that all temperatures were within allowable values such that there would be no impact on package performance. Likewise, according to the SARP structural chapter, there were no interferences between package components at NCT due to thermal expansions and there was no loss of structural integrity.

3.4 Thermal Evaluation Under Hypothetical Accident Conditions

The SARP thermal chapter presented a HAC thermal analysis of the D2W core within the Model 1 container that assumed the outer layers of the package were removed. This thermal analysis used the same thermal code described above for NCT. According to the SARP thermal chapter, the applicant chose the initial temperature conditions as the steady-state temperatures calculated for the hot NCT with insolation; in addition, the exterior surface exposed to the fire had an emissivity and absorptivity of 0.8 and the fire had an emissivity of 0.9. This assumption maximized internal package temperatures and, therefore, stresses associated with package pressure.

In addition, the applicant provided supplemental information in a response to a request for additional information (ADAMS Accession No. ML21140A092). In their response the applicant stated that a numerical thermal analysis was performed for the D2W core within the Model 1 container. This analysis included the effect of having a locally damaged surface due to the puncture test. The results showed that the maximum interior temperature and the maximum package exterior temperature were comparable to previously reviewed thermal results. The supplemental information noted that the previous analysis was for a D1G package with similar weights, materials of construction, and heat-transfer paths as the current package; it also noted that the previously reviewed content had a higher decay heat. Staff finds that the HAC thermal aspects of the current Model 1 container amendment are similar to the previously reviewed and approved D1G package.

According to the SARP structural and thermal chapters, results from the HAC numerical analysis showed that package components did not reach melting temperatures and that stresses, including thermal stresses, associated with the package were such that containment integrity would be maintained.

3.5 Evaluation Findings

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

4.0 CONTAINMENT EVALUATION

The applicant based the containment analysis on the Model 1 container which consisted of cylindrical steel side walls, steel removeable closure head with high strength bolts, steel bottom end, steel inner vessel, reinforced concrete covering, and steel outer shell. The applicant indicated that there are no penetrations within the package, no valves, and that the package is not continuously vented. The applicant secured a D2W core barrel assembly (i.e., the content) inside the Model 1 container using a steel ring that is bolted to the inner vessel with high-strength bolts.

The SARP structural chapter described the Type B package as an all-welded, single use container. The applicant designed and constructed the packaging in accordance with Naval standards and the SARP drawings. The staff previously reviewed and concurred on the Model 1 container. The SARP general information, operation, and procedure chapters indicated that many of the analyses, operations, and programs (i.e., testing, maintenance) associated with the package would follow those from the previously reviewed package.

4.1 Description of Containment System and Content

According to the SARP containment chapter, the containment boundary consisted of thick-walled components, including a steel inner vessel, a steel closure head with bolts attaching it to the inner vessel, a steel closure ring, a steel end cap, and multi-pass welds that seal these components. The applicant stated that the containment boundary welds have procedures, quality control practices, qualifications, and nondestructive test requirements for each weld pass. The SARP containment chapter stated that the welds also provide positive closure to prevent unintentional opening. In addition, the containment chapter stated there were no seals, no valves, no pressure relief valves, and no containment boundary penetrations. The containment chapter also stated that the package was not continuously vented.

The SARP containment chapter identified that the radioactive material in the package is associated with the activated metal of the core barrel assembly, surfaces contaminated with activated corrosion products, and crud that is within a small quantity of residual water. The SARP containment chapter listed the radionuclides and calculated the activity associated with the activated metal and the crud. Although the activity associated with the activated metal was greater than an A_2 quantity, the applicant determined that activity associated with releasable content was less than an A_2 quantity.

The SARP structural chapter included a calculation which determined the time needed for hydrogen generated from radiolysis of the residual water to reach a pre-determined concentration. In addition, the applicant provided supplemental information in a response to a request for additional information (ADAMS Accession No. ML21140A092) that listed the conservatisms associated with the radiolysis calculation. These conservatisms included using a higher volume averaged energy deposition rate in water, neglecting the effect of source decay, and applying a 1.15 factor to the rate of energy deposition in water. Staff also noted that the radiolysis calculation did not account for the presence of a catalyst to reduce hydrogen concentration levels. A CoC condition was included based on the applicant's specified time generated by the calculation.

4.2 Containment Under Normal Conditions of Transport

The SARP containment chapter stated that there is no release of radioactive material during NCT because the structural chapter concluded there was no reduction in either the sealing capability or the containment system effectiveness. Based on this and the fact that there is less than an A_2 of releasable material, the staff finds that the package meets 10 CFR 71.51(a)(1) to a sensitivity of 1×10^{-6} A_2/hr.

4.3 Containment Under Hypothetical Accident Conditions

According to the SARP structural and thermal chapters, the all-welded containment boundary maintained its integrity under structural-related (e.g., drop, impact) and thermal HAC, thus there is no loss of the irradiated core or crud. Based on this and the fact that there is less than an A_2 of releasable material, the staff finds that the package meets 10 CFR 71.51(a)(2).

4.4 Evaluation Findings

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

5.0 SHIELDING EVALUATION

The applicant requested an amendment to the certificate for the Model 1 container. The proposed change related to the shielding evaluation is the inclusion of a D2W core barrel assembly as authorized contents. The Model 1 container with the D2W core barrel assembly is referred to as a D2W package. The objective of this review is to confirm that the D2W package meets the external radiation requirements of 10 CFR Part 71 under NCT and HAC.

5.1 Description of Shielding Design

5.1.1 Design Features

The applicant stated that the D2W package consists of the Model 1 container, a Model 1 closure head, the D2W core basket/thermal shield (CB/TS) assembly, the D2W CB/TS removal cover, and the preload ring. The following components provided shielding: the Model 1 inner vessel, reinforced concrete outer vessel, outer wrapper, removal cover, and closure head. After reviewing the application, staff finds the applicant's description and the SARP drawings provide sufficient detail to confirm the applicant's analyses.

5.1.2 Summary Tables of Maximum Radiation Levels

The applicant summarized calculated radiation levels in SARP Tables A.5.1-1 and A.5.1-2 for NCT and HAC, respectively. The staff finds that the calculated radiation levels for conditions normally incident to transport are below the maximum radiation levels allowed for non-exclusive use shipments of packages under 10 CFR Part 71 (i.e., 200 mrem/hr on the package surface and 10 mrem/hr at 1 meter). The staff also finds that the calculated radiation levels under HAC are below the maximum radiation levels allowed under 10 CFR Part 71 (i.e., 1000 mrem/hr at 1 meter from the package surface).

5.2 Radiation Source

5.2.1 Gamma Source

The package contents consisted of activation sources and crud; therefore, the irradiation history determined the source term magnitude. The applicant stated that the crud consisted entirely of ^{60}Co. For activation sources in the fuel region, the applicant derived the three-dimensional source distribution from a lifetime average neutron flux distribution. The applicant then evaluated different core power histories to determine the activation source outside of the fuel region since the peak flux location changes during the core lifetime. The applicant provided the power histories in SARP Table A.5.2-1, and the applicant selected a power history that maximized the neutron flux for each activation region. Staff finds this acceptable since this maximizes the source activity.

The applicant used a program similar to ORIGEN-S to develop the time- and flux-dependent activation nuclide concentrations. The applicant's program used neutron flux to set up and solve an array of ordinary differential equations to determine nuclide number density vectors. The applicant then verified the results from their program with ORIGEN-S. The applicant's method accounted for the spatial variations in the neutron flux and maximized the activation of the materials. The applicant also applied an additional administrative factor to increase the flux above and below the fuel region. Because ORIGEN-S is a well-vetted code with a long history of use in similar applications and the additional margin provided by using administrative factors, staff finds the applicant's method acceptable as it over-predicts the activation of source materials.

The applicant presented the activation source strength from all tracked nuclides in SARP Table A.5.5-2. For crud sources, the applicant based the calculated activity using a bounding, end-of-life pipewall measurement, the total wetted surface area, and historical crud concentrations. End-of-life pipewall measurement referred to the applicant's periodically measuring the crud buildup over the reactor vessel's entire life span and using this trend to predict crud concentrations at shutdown. The applicant compared the trendline from all similar power plants and used the highest end-of-life crud activity among those vessels. The applicant showed the most limiting crud activity lies well above the 95% confidence interval of the rest of the fleet. This methodology is consistent with previous, NRC-approved analyses for Reactor Compartment Disposal Packages. The applicant presented crud source strengths in SARP Table A.5.2-3. The applicant assumed only crud present in residual water can relocate and collect in another location. Staff finds this acceptable since the crud is not easily removed and would have to traverse a tortuous path to relocate to the inner vessel. The applicant determined that the radiation limits of 10 CFR 71 would still be met if all the removable crud were to relocate into a bounding configuration. Given the pipe conditions and continuous filtration during operation, and the negligible contribution of crud to dose, the staff finds the applicant's crud source determination acceptable.

5.2.2 Neutron Source

There is no significant neutron source from the new contents of this package.

5.3 Shielding Model

5.3.1 Configuration of Source and Shielding

The applicant modeled a stronger radiation source than would be present due to the conservative assumptions discussed in SER Section 5.2 (e.g., use of bounding flux, administrative factors). The applicant ignored the presence of rebar within the concrete. The applicant also modeled the structures important to shielding at the minimum thickness allowed. Staff finds these assumptions acceptable since they will over-predict the external dose rates.

Under NCT, the applicant modeled potential fractures by removing shielding material from the model in a manner that bounds any potential fracture plane. The applicant modeled the activated components as distinct items which are shifted to the maximum extent possible such that calculated radiation levels increase. The applicant assumed that any residual water and movable crud entirely fills any penetration volume and modeled the remaining water and movable crud immediately adjacent to the penetration being evaluated. Staff finds these modeling assumptions acceptable since they conservatively over-predict calculated dose rates by minimizing the distance between the package surface and the source.

For HAC, the applicant conservatively assumed the outer steel wrapper and concrete are lost as well as reduced the entire closure head thickness to account for a puncture accident (i.e., assumed a material loss greater than can be expected under HAC). The applicant also modeled potential fractures by removing material from the shielding model in a manner that bounds any potential fracture plane. In addition, the applicant determined the components will shift to contact the inner vessel and modeled the components shifted to the largest extent possible. Staff finds these assumptions acceptable as both will maximize calculated external radiation levels.

5.3.2 Material Properties

Staff reviewed the material properties specified in the model and found them to be appropriate for the actual construction and contents of the package. The applicant presented a summary of mass and number densities used in the analysis in SARP Table A.5.3-1.

5.4 Shielding Evaluation

5.4.1 Methods

The applicant calculated the external radiation using different methods for activation and crud sources. The applicant used MC21, a continuous-energy, Monte Carlo code that was developed jointly by Knolls Atomic Power Laboratory and Bettis Atomic Power Laboratory to evaluate neutron and photon transport from activation sources. The code has been benchmarked to Advanced Test Reactor data and other benchmark models have been shown to agree with results produced by MCNP-5 which has a long history of use in NRC approved shielding applications. In addition, staff reviewed the applicant's selected convergence criteria and finds reasonable assurance the applicant's results fall within a 95% confidence interval. Because MC21 has been shown it can model intricate geometries necessary for shielding calculations and the applicant used appropriate convergence criteria, staff finds the applicant's use of MC21 acceptable.

For crud, the applicant used MCNP-4C which is well vetted and has a long history of use in shielding applications. To obtain calculation results more rapidly, the applicant employed a supplemental point-kernel method, which is appropriate for systems with only gamma radiation, in conjunction with MCNP-4C. This approach functioned much like the SPAN computer code which previous staff review found acceptable. Considering the applicant used the point-kernel method for more rapid results and checked some results with robust MCNP calculations, the staff finds the applicant's methodology acceptable.

5.4.2 Input and Output Data

Due to the sensitive nature of the application, the staff did not perform a confirmatory analysis using the applicant's input data. However, the staff found the information in the SARP sufficient for assessing the expected dose results.

5.4.3 Flux-to-Dose-Rate Conversion

The applicant used the DT-702/PD gamma flux-to-dose conversion factors with its MC21 and MCNP/point kernel evaluations. Staff finds this acceptable as the applicant has used these conversion factors in applications previously reviewed by NRC staff. In addition, the applicant applied an additional conservative administrative factor which overestimates radiation level contributions. The applicant presented these factors in SARP Table A.5.4-1.

5.4.4 External Radiation Levels

The applicant applied an additional scaling factor to the calculated NCT external radiation levels to conservatively increase the radiation levels. The applicant presented the NCT external radiation levels in SARP Table A.5.1-2. The applicant did not apply this additional factor to the HAC dose rates in SARP Table A.5.1-3 because there is significant margin between the peak dose rates and the limits in 10 CFR Part 71. Staff finds the dose rates presented in SARP Tables A.5.1-2 and A.5.1-3 acceptable.

5.5 Findings

The staff performed its review following the guidance provided in NUREG-2216, "Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material." Based on staff review of the methods, analyses, and information presented in the application, and prior staff review, for the reasons discussed above, the staff finds reasonable assurance that the shielding requirements of 10 CFR Part 71 will be met with the proposed contents and packaging design.

6.0 CRITICALITY

The staff reviewed the application and determined that the content is not fissile material regulated under 10 CFR 71.55 and 10 CFR 71.59; therefore, this section does not apply.

7.0 MATERIALS EVALUATION

7.1 Container

The proposed revision to the Model 1 container modified neither the container's fabrication requirements, materials of construction, nor the material property values used in the structural, thermal, and shielding analyses. The staff also noted that the service conditions (e.g., heat and radiation exposures) are comparable to those in the previously approved versions of the package. The irradiated metal and crud contents of the D2W core barrel neither introduced additional heat; nor exposed the package materials to radiation levels that are considered capable of affecting materials performance. Therefore, the staff finds the materials design of the container to be acceptable.

7.2 Contents

The applicant evaluated the structural performance of the container's contents (i.e., a D2W core barrel) to demonstrate that the geometric configuration of the contents under normal conditions of transport and hypothetical accident conditions is consistent with that assumed in the shielding analysis. The applicant assessed the brittle fracture performance of the content materials to evaluate the potential for the contents to fracture and shift within the container. The staff reviewed the applicant's analysis. The staff confirmed that the applicant used appropriate fracture analysis methods as well as materials toughness values to account for the potential fracture and shifting of the core barrel in the shielding analysis. Therefore, the staff finds the applicant's evaluation of the content's brittle fracture performance to be acceptable.

The applicant also stated that the D2W core barrel does not introduce galvanic or other detrimental reactions. The staff noted that prior revisions of the package evaluated the potential for residual water in the metallic contents to cause corrosive reactions. The staff also noted that the core barrel previously operated in a reactor water environment. Therefore, staff determined that any corrosion occurring during transportation in an ambient air environment should be minor and have no meaningful impact on the package performance. Therefore, after considering the content materials, the container materials, and the amount of residual water, the staff finds the applicant's evaluation of corrosive reactions to be acceptable.

7.3 Evaluation Findings

Based on a review of the statements and representations in the application, the NRC staff concludes that the materials used in the transportation package design have been adequately described and evaluated and that the package meets the requirements of 10 CFR Part 71.

8.0 PACKAGE OPERATIONS

Staff reviewed the proposed change and determined that it did not impact the staff's previous SER findings regarding the package acceptance tests and maintenance program. Therefore, the staff finds that a new evaluation is not needed.

9.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM REVIEW

Staff reviewed the proposed change and determined that it did not impact the staff's previous SER findings regarding the package acceptance tests and maintenance program. Therefore, the staff finds that a new evaluation is not needed.

CONDITIONS

The CoC includes the following condition(s) of approval:

Condition 5(a)(2) was modified consistent with the new content and to remove sea transport references.

Condition 5(a)(3) was modified to remove references to specific package drawings.

Condition 5(b) was modified to identify the new content.

Condition 6(a) was deleted and Conditions 6(b) and 6(c) were renumbered.

Condition 6(b was clarified to be better defined.

Condition 6(c) was revised to identify the new content and to specify the minimum number of days after shutdown at which transport can commence.

Condition 8 was modified to identify the allowable number of days to complete the shipment.

The references section has been updated to include this request.

Minor editorial corrections were made.

CONCLUSIONS

Based on the statements and representations contained in the application, as supplemented, and the conditions listed above, the staff concludes that the design has been adequately described and evaluated, and the Model No. 2000 package meets the requirements of 10 CFR Part 71.

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