UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

Safety Evaluation Report
Docket No. 71-9793
Model No. M-140 Package
Certificate of Compliance No. 9793
Revision No. 21

Summary

By letter dated March 23, 2021, (Agencywide Documents Access and Management System [ADAMS] Accession No. ML21105A528), as supplemented on December 20, 2022, the U.S. Department of Energy, Division of Naval Reactors, (DOE-NR or the applicant) requested renewal and amendment to Certificate of Compliance No. 9793 for the Model No. M-140 package.

The U.S. Nuclear Regulatory Commission (NRC) staff performed its review of the M-140 package utilizing the guidance provided in NUREG-2216, "Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material: Final Report." Based on the statements and representations in the application, as supplemented, the analyses performed by the applicant demonstrate that the package provides adequate structural, thermal, containment, shielding, and criticality safety protection under normal conditions of transport (NCT) and hypothetical accident conditions (HAC), therefore the NRC staff concludes that the package meets the requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 71.

1.0 General Information Evaluation

1.1 Packaging

The M-140 is a stainless steel package for transporting spent fuel. The overall package dimensions are 98 inches in diameter and 194 inches high. The package body is 14 inches thick with a closure head that is secured by 36 wedge assemblies located radially around the inside diameter. Penetrations in the closure head and body include an access port for fuel loading, vent and drain ports, water inlet and outlet penetrations, and a thermocouple penetration. The cask closure head and penetrations are sealed with plugs and double ethylene propylene O-ring seals. A stainless steel protective dome is positioned over the closure head. The cask body has 180 external vertical cooling fins, and a support ring is welded to these cooling fins. The support ring is bolted to a rail car mounting ring during transport. The fuel is positioned within an internals assembly. The internals assembly is composed of stacked spacer plates that have openings for the spent fuel modules. The maximum weight of the package, including contents, is 375,000 pounds.

1.2 Contents

The applicant requested a revised thermal restrictions support shipment of longer-lived D2W cores, use of a single thermal restriction criterion for each fuel type, and incorporation of a revised S6W fuel assembly grapple adapter design.

1.3 Conclusion

The changes made to the general information section were adequate and do not affect the continued ability of the package to meet the requirements in 10 CFR Part 71.

2.0 Structural Evaluation

The Naval Reactors application contained revised safety analysis reports for packaging (SARP) for the proposed DOE-NR certificate of compliance USA/9793/B(U)F-85 (DOE-NR) and requested that the staff review it to allow shipment of D2W and S6W spent fuel in the M-140 spent fuel shipping container. The staff reviewed the application, as supplemented, to verify that the structural performance of the packaging components meets the requirements of 10 CFR Part 71.

2.1 Background and Discussion

The M-140 nuclear spent fuel shipping packaging (herein referred to as the M-140 packaging) is certified as a Type B package for shipment of fissile and highly radioactive material. The M-140 package is designed to transport spent nuclear fuel from several different core types. The packaging is the same for all cargos but can have different internal designs to accommodate different spent fuel modules for different core types.

In this application, the applicant proposed changes to the D2W SAR and S6W SAR (Reference 1) for the D2W and S6W spent fuel modules, respectively, in the M-140 packaging. The changes are associated with the DOE-NR certificate of compliance thermal restrictions and support for: (i) shipment of longer-lived D2W cores, and (ii) use of a single thermal restriction criterion for each fuel type, and (iii) incorporation of a revised S6W grapple adapter design. As a result, the applicant updated temperatures in the SARs based on its updated thermal evaluations presented in chapter 3.0, “THERMAL EVALUATIONS,” and revised the structural evaluations to include the changed temperatures in the SARs for the D2W and S6W spent fuel modules and submitted the results of the evaluations to demonstrate compliance with 10 CFR Part 71.

The applicant stated that it did not update the structural evaluations for the D2W and S6W spent fuel modules if the temperature changes are bounded by the existing structural evaluations of the D2W and S6W spent fuel modules.

2.2 Evaluations for D2W Spent Fuel Module in the M-140 Package

2.2.1 Normal Conditions of Transport

<u>Temperature</u>: The applicant calculated the new maximum temperatures in chapter 3.0, “THERMAL EVALUATION,” of the D2W SAR and provided the results in table 3.3-4. Table 2.6--1 also presents the new calculated maximum D2W temperatures with the maximum design temperatures for the designs of the packaging components. The staff reviewed table 2.6-1 and found that the calculated new maximum temperatures exceed the maximum design temperatures in the four components (i.e., wedge region of container body flange, closure head, closure head seal and protective dome). Since the calculated new maximum temperatures exceed the maximum design temperatures of those components, the staff issued a request for additional information (RAI) in October 5, 2022 (ML22264A313), in which the staff requested the applicant to provide technical explanations and justifications of: (i) why the exceedance of the calculated new maximum temperatures over the maximum design temperatures of the components is acceptable, and (ii) how the structural designs of the components are adequate and safe with the calculated new maximum temperatures.

The applicant provided the responses to the RAI in its supplement dated December 20, 2022. The applicant stated that table 2.6-1 provides a summary of the package temperatures with D2W cargo for NCT and compares the results with the maximum package temperatures analyzed in the "Core Independent M-140 Safety Analysis Report for Packaging," [SAR] (Reference 2). The applicant further stated that, although the temperatures for the four components (wedge region of container body flange, closure head, closure head seal, and protective dome) exceed the temperatures analyzed in the Core Independent M-140 SAR by up to 11°F, the temperatures provided in table 2.6-1 of the D2W SAR are acceptable because there is sufficient conservatism in the calculated temperatures to bound the temperature increase. The applicant provided the following supplemental information:

(1) There are multiple assumptions in the D2W thermal model, which produce conservative structural component temperatures that slightly exceed the design temperatures of the Core Independent M-140 SARP. The temperature at the wedge region of the packaging body flange has the largest difference and exceeds the design temperature by 11°F. All of the identified components are outside of the secondary containment boundary and are primarily influenced by the solar load. The thermal model conservatively assumes a full solar load on all external surfaces as steady state, rather than a cyclic load required by 10 CFR 71.71(c)(1) (12 hours on, 12 hours off). Thus, the total solar load is doubled. Sensitivity studies indicate that the use of a steady state solar load overestimates temperatures by greater than 11°F such that the component temperatures would be less than the design temperatures in the cyclic solar load case.

(2) Although the calculated temperatures are judged to be sufficiently conservative to bound the differences, the Core Independent M-140 SARP shows that most of the structural components in the four regions identified in table 2.6-1 have margins of over 20 percent to the respective yield strengths or strain limits. Additionally, evaluations identify that ultimate strengths are not exceeded in the regions where yield strengths are exceeded (i.e., the wedges and packaging flange ligaments in the wedge region of the container body flange). The worst-case evaluation (section 2.10.2.3.2.1) of the Core Independent M-140 SARP has a safety margin of 7.9 percent to the ultimate strength with the design base temperature. Additional evaluation with the 11°F temperature increase results in an acceptable safety margin of 6.8% to the ultimate strength. Additionally, the increase in temperature of the closure head seal (from 192°F to 199°F) is within the maximum service temperature for the seal material, which is 250°F. Therefore, the increase in temperature to the components does not impact their relied upon functions described in the SAR.

The staff reviewed the responses and found them acceptable because (i) the technical assumption in the thermal model is conservative [i.e., steady state, rather than a cyclic load required by 10 CFR 71.71(c)(1)], (ii) the four structural components (i.e., wedge region of container body flange, closure head, closure head seal and protective dome) are outside of the secondary containment boundary, (iii) most of the structural components in the four regions identified in table 2.6-1 have margins of over 20 percent to the respective yield strengths or strain limits, and (iv) none of the structural components exceeds the ultimate strengths.

Pressure: The applicant calculated the new maximum normal pressure in chapter 3.0, "THERMAL EVALUATION," and provided the results in section 3.3.4, "Maximum Internal Pressure." The calculated maximum normal condition pressure for the package is 28.1 psig. The applicant concluded that this pressure is acceptable since it is less than the 75.0 psig worst case pressure analyzed in the Core Independent M-140 Safety Analysis Report for Packaging (Reference 2).

The staff agrees with the applicant's conclusion and finds it acceptable because the structural performance of the packaging as described in the Core Independent M-140 SARP when subjected to 75.0 psig, which was previously reviewed and approved by the staff, is applicable and bounds the structural performance of the D2W spent fuel module in the M-140 package when subjected to 28.1 psig.

The staff determines that the D2W spent fuel module in the M-140 package satisfies the regulatory requirements of 10 CFR 71.71.

2.2.2 Hypothetical Accident Conditions

The applicant evaluated the D2W spent fuel module in the M-140 packaging for the HAC as required by 10 CFR 71.73. The applicant analyzed the D2W spent fuel module in the M-140 package using the closed-form solutions and the finite element (FE) computer program, ABAQUS. DOE-NR previously used ABAQUS for the evaluations of the D2W spent fuel in the M-140 package to demonstrate compliance with the regulatory requirements for HAC in 10 CFR 71.73.

2.2.2.1 Free Drop

The regulation in 10 CFR 71.73(c)(1) requires that a package needs to be demonstrated for structural adequacy by subjecting the package to a free drop through the distance of 30-foot onto a flat, unyielding, horizontal surface in a position for which maximum damage is expected. In order to determine the orientation that produces the maximum damage, the applicant evaluated the D2W spent fuel module in the M-140 packaging for impact orientations in which the package strikes the impact surface. The applicant considered three drop configurations: (i) top drop, (ii) bottom drop, and (iii) side drop.

The results of the drop analyses using the closed-form solutions and the ABAQUS FE program for the structural components are provided in appendices 2.10.1 through 2.10.3 of the D2W SAR. The results of the top drop analyses for the D2W spent fuel module in the M-140 packaging show that the adaptive hardware used to ship the fuel cells remains undamaged. The results of the bottom drop analyses show that the adaptive hardware used to ship the fuel cells remains undamaged, with a small deformation of the energy absorbers and their top plates. Additionally, the results of the side drop analyses for the D2W spent fuel module in the M-140 packaging show that the cell housings and the fuel clusters remain elastic, which indicates that the primary containment is maintained.

The staff reviewed the results of the structural analyses presented in appendices 2.10.1 through 2.10.3 of the application, and, based on its reviews and verifications, the staff confirmed the applicant’s findings.

The staff determines that the application satisfies the regulatory requirements of 10 CFR 71.73(c)(1).

2.2.2.2 Puncture

The regulation in 10 CFR 71.73(c)(3) requires that free drop of the specimen through the distance of 40 inches onto the upper end of a solid, vertical, cylindrical, mild steel bar mounted on an essentially unyielding, horizontal surface in a position for which maximum damage is expected.

The applicant evaluated the performance of the D2W spent fuel module in the M-140 package under puncture and found that there is no change on the puncture performance of the D2W module by the proposed changes. The applicant concluded that there is no update on the evaluations for puncture and the previous puncture evaluations, which were reviewed and approved by the staff, still remain valid without any updates.

The staff reviewed the statements and agreed with the applicant's statements that the previous evaluation for puncture remains valid and acceptable. Based on the review of the evaluation, the staff determines that the application meets the regulatory requirements of 10 CFR 71.73(c)(3).

2.2.2.3 Thermal

The regulation in 10 CFR 71.73(c)(4) requires exposure of the package to an average flame temperature of at least 1,475°F for a period of 30 minutes.

The applicant performed thermal evaluation of the D2W spent fuel module in the M-140 packaging under HAC in chapter A.3, "THERMAL EVALUATION," of the application. The results of the thermal evaluations indicate that the primary containment is maintained in the hypothetical fire accident because the fuel clad performance limits are not exceeded. Therefore, the applicant concluded that the previous evaluations, which were reviewed and approved by the staff, still remain valid.

The staff reviewed the evaluations presented by the applicant and found them acceptable. Additional detailed reviews and safety evaluations by the staff on the applicant's thermal evaluations are provided in chapter 3 of this SER.

The staff determines that the application satisfies regulatory requirements of 10 CFR 71.73(c)(4).

2.3 Evaluations for S6W Spent Fuel Module in the M-140 Packaging

2.3.1 Normal Conditions of Transport

<u>Temperature</u>: The applicant calculated the new maximum temperatures in chapter 3.0, "Thermal Evaluation," of the S6W SAR (Reference 1). Table 2.6-1 presents the new calculated maximum temperatures with the maximum design temperatures of the package components. The applicant concluded that the structural performance of the S6W spent fuel module in the M-140 packaging is acceptable since the new calculated maximum temperatures are less than the maximum design temperatures. The staff reviewed table 2.6-1 and confirmed that the new calculated maximum temperatures are less than the maximum design temperatures of the packaging components.

Pressure: The applicant calculated the new maximum NCT pressure in chapter 3.0, “THERMAL EVALUATION,” of the S6W SAR. The calculated maximum NCT pressure for the package is 26.0 psig. The applicant concluded that this pressure is acceptable since it is less than the 75.0 psig pressure analyzed in the Core Independent M-140 SARP.

The staff agrees with the applicant's conclusions and finds them acceptable because the structural performance of the Core Independent M-140 SARP when subjected to 75.0 psig with the maximum design temperatures, which were previously reviewed and approved by the staff, is applicable and bounds the structural performance of the S6W spent fuel module in the M-140 packaging.

The staff determines that the S6W spent fuel module in the M-140 packaging satisfies the regulatory requirements of 10 CFR 71.71.

2.3.2 Hypothetical Accident Conditions

The applicant evaluated the S6W spent fuel module in the M-140 packaging for the HAC free drop, puncture, and thermal tests as required by 10 CFR 71.73. The applicant analyzed the S6W spent fuel module in the M-140 packaging using the closed-form solutions and a computer program, CRUSHTAB, which were used for the evaluations of the previous S6W spent fuel in the M-140 packaging in Reference 1 to demonstrate compliance with the regulatory requirements for HAC in 10 CFR 71.73. The CRUSHTAB program was used to determine the impact deformations and the center-of-mass decelerations of the structural components in a packaging impacting an unyielding surface for free drops. The staff previously reviewed and approved the adequacy of using the CRUSHTAB program for drop analyses in S6W SAR (Reference 1).

2.3.2.1 Free Drop

The regulation in 10 CFR 71.73(c)(1) requires that a package needs to be demonstrated for structural adequacy by subjecting the package to a free drop through the distance of 30-foot onto a flat, unyielding, horizontal surface in a position for which maximum damage is expected. In order to determine the orientation that produces the maximum damage, the applicant evaluated the S6W spent fuel module in the M-140 packaging for impact orientations in which the package strikes the impact surface. The applicant considered three major drop configurations: (i) flat top drop, (ii) side drop, and (iii) flat bottom drop.

The results of the drop analyses using the CRUSHTAB program for the structural components of the S6W spent fuel module in the M-140 packaging are provided in appendices 2.10.2 through 2.10.6 of the application. The results of the top drop analyses for the S6W spent fuel module in the M-140 packaging show that all parts of the S6W shipping assembly, guide spacers, and pedestal remain elastic. The guide spacers stay attached to the internal guide plate and do not load the packaging access plug or closure head. The grapple adapter stays attached to the manifold, and the manifold to the fuel assembly. The internal forces on the packaging access plug or closure head from the S6W shipping assembly and pedestal are less than the allowable forces determined in Reference 2.

The results of the side drop analyses for the S6W spent fuel module in the M-140 packaging show that the fuel assembly remains elastic, which indicates that the primary containment is maintained. Additionally, the results of the bottom drop analyses for the S6W spent fuel module in the M-140 packaging show that the calculated stresses in the fuel region remain elastic, which indicates that the primary containment is maintained.

The staff reviewed the results of the CRUSHTAB analyses presented in appendices 2.10.2 through 2.10.6 of the application, and, based on its reviews and verifications, the staff confirmed the applicant's findings.

The staff determines that the application satisfies the regulatory requirements of 10 CFR 71.73(c)(1).

2.3.2.2 Puncture

The regulation in 10 CFR 71.73(c)(3) requires that free drop of the specimen through the distance of 40 inches onto the upper end of a solid, vertical, cylindrical, mild steel bar mounted on an essentially unyielding, horizontal surface in a position for which maximum damage is expected.

The applicant evaluated the puncture performance of the S6W spent fuel module in the M-140 packaging and the provided the results of the evaluations in appendix 2.10.7 of the application. The results of the analyses showed that the bottom drop puncture test following the 30-foot side drop results in no additional damage to the control rod beyond that assumed in the 30-foot side drop analysis. The applicant concluded that the S6W content is not damaged by the puncture accident, and, as a result, the post puncture accident damage is the same as the post 30-foot drop accident damage, as summarized in subsection 2.7.2, "Puncture," of the SAR.

Based on the review of the analyses results, the staff determines that the application meets the regulatory requirements of 10 CFR 71.73(c)(3).

2.3.2.3 Thermal

The regulation in 10 CFR 71.73(c)(4) requires exposure of the package to an average flame temperature of at least 1,475°F for a period of 30 minutes.

The applicant performed thermal evaluations of the S6W spent fuel module in the M-140 packaging under HAC in chapter A.3, "THERMAL EVALUATION," of the application. The results of the thermal evaluations indicate that: (i) there is no degradation of the sealing capability of the containment system, (ii) all calculated stresses are less than the allowable stresses, (iii) there is no loss of radioactive material, and (iv) the primary containment of the S6W spent fuel module is maintained under HAC.

The staff reviewed the evaluations presented by the applicant and found them acceptable. Additional detailed reviews and safety evaluations by the staff on the applicant's thermal evaluations are provided in chapter 3 of this SER.

The staff determines that the application satisfies regulatory requirements of 10 CFR 71.73(c)(4).

2.4 Evaluation Findings

Based on a review of the statements and representations in the application and the responses to the RAI, the staff concludes that the structural design has been adequately evaluated and that the D2W and S6W spent fuel modules in the M-140 packaging transportation package have adequate structural integrity to meet the structural requirements of 10 CFR Part 71.

2.5 References

1. WAPD-REO(C)-1856 – S6W Spent Fuel in the M-140 Safety Analysis Report for Packaging.

2. WAPD-REO(C)-1600 – Core Independent M-140 Safety Analysis Report for Packaging Revision 15, October 2011.

3.0 Thermal Evaluation

3.1 Description of Thermal Design

3.1.1 Design Features

The M-140 spent fuel shipping package includes a right circular cylindrical shell that is a 14-inch thick stainless steel forging with flange, 12-inch thick steel bottom plate, and 13-inch thick stainless steel closure head. Cooling fins are welded to the exterior shell of the package to aid in the passive cooling of the package. The closure head is held in place by a wedge closure system and is sealed using concentric O-rings against the exterior shell flange. The package bottom includes concentric stainless steel rings that act as an energy absorber. The loading and unloading operations of spent fuel are via an access opening in the closure head; the access opening is closed by a bolted shield plug. A stainless steel dome, which is attached to the packaging body, covers the closure head during transport. Although the M-140 packaging has penetrations for cooling water circulation, venting, and thermocouples, they are not used during transport and are sealed during shipment with plugs and double O-ring seals; therefore, there are no valves and no continuous venting from the packaging. The spent fuel content (e.g., S6W or D2W core types) is held in place within the packaging by an internals assembly composed of stacked spacer plates. According to the Core Independent M-140 SARP, the Type B fissile package is designed and constructed in accordance with military (MIL), American Society of Mechanical Engineers (ASME), and American National Standards Institute (ANSI) standards and the drawings contained in the SARP.

The M-140 package was previously reviewed and certified, including for the bounding contents described in the Core Independent M-140 SARP. The S6W and D2W M-140 SARP's Acceptance Tests and Maintenance chapter and the Operating Procedures chapters referred to the corresponding chapters in the previously reviewed Core-Independent M-140 SARP. This thermal evaluation is based on the thermal effects of the M-140 package with S6W and D2W modules and the internals assembly.

3.1.2 Content Decay Heat

According to the S6W and D2W M-140 SARP Containment chapters, the package's activity is associated with the remaining fissionable material within the spent fuel (e.g., fission products, actinides), irradiated structural components, irradiated corrosion products (crud) that adhere to the surfaces of the fuel modules and components, and the irradiated crud deposited on the interior surfaces of the M-140 package. The SARP noted that the fuel cladding is the boundary that contains the spent fuel's remaining fissionable material and that the M-140 package acts as a containment boundary for the package's internal components and irradiated crud.

The SARP's Thermal chapter for the S6W indicated that decay heat was determined using depletion calculations associated with the content. The thermal analyses for the S6W were based on a conservative decay heat relative to the 41,712 Btu/hr value reported in the certificate of compliance.

The SARP thermal analyses for the D2W were based on a container decay heat of 45,000 Btu/hr for NCT and 46,124 BTU/hr for HAC, and, according to the telecon summary dated August 16, 2022 (ML23124A270), this decay heat is greater than what can be loaded and shipped. In addition, the Certificate of Compliance associated with the D2W cargo stated that draining of the M-140 shipping container would not occur until content decay heat was at or below this value.

3.1.3 Summary of Temperatures

According to the S6W and D2W M-140 SARP thermal chapters, the maximum temperatures of the accessible surface of a M-140 package with S6W and D2W cargoes at hot normal conditions, no insolation, and maximum decay heat were less than the 185°F regulatory limit for exclusive use shipment described in 10 CFR 71.43(g).

3.1.3.1 S6W Contents

The S6W M-140 SARP Thermal chapter and Structural chapter provided M-140 packaging and S6W component temperatures (e.g., packaging's closure head, packaging internals, fuel modules) for hot normal conditions of transport. According to the S6W M-140 SARP Structural chapter, NCT temperatures of package components, including the closure head seal, were lower than design values. Likewise, the S6W M-140 SARP Thermal chapter and Containment chapter indicated that fuel temperatures at NCT and HAC were within the acceptance criteria and that cladding integrity would be maintained.

Regarding cold temperatures, the S6W M-140 SARP Structural chapter indicated that analyses addressed the minimum cold temperature (-40°F), including the effects of differential thermal contraction and the potential for brittle fracture, and concluded acceptable package performance at the minimum cold temperature. In addition, the Core-Independent M-140 SARP indicated that -40°F is within the allowable temperature range of the M-140 O-ring seals.

3.1.3.2 D2W Contents

The D2W M-140 SARP Thermal and Structural chapters provided M-140 and D2W component temperatures (e.g., package's closure head and seal, container internals, fuel modules, fuel) for hot normal conditions of transport, with and without insolation. Although the structural chapter indicated that many of the component temperatures had margin with the design temperature values, it also indicated that a few components had reported temperatures slightly above the design temperature. However, it was noted in the telecon summary (dated August 16, 2022) that these temperatures were below allowable temperatures; in particular, the seal temperature had sizeable temperature margin with the allowable temperature, as noted in the Core Independent M-140 SARP. The RAI responses noted that the reported temperatures for the components with higher temperatures would be lower and have margin with the design temperature values if the conservative assumption of doubling the insolation was reduced, as indicated in the SARP table that compared component temperatures of a model with and without insolation. Therefore, it was noted that the safety impact was maintained.

The SARP Thermal, Structural, and Containment chapters and the August 16, 2022, telecon summary indicated that results from the HAC numerical analysis showed that fuel cladding temperatures were within allowable temperatures and that cladding integrity would be maintained.

Regarding cold temperatures, the D2W M-140 SARP Thermal and Structural chapters indicated that the minimum allowable temperature of the M-140 and its cargo is -40°F. In addition, the Core-Independent M-140 SARP indicated that -40°F is within the allowable temperature range of the M-140 O-ring seals.

3.1.4 Summary of Maximum Pressures

3.1.4.1 S6W Contents

According to the S6W M-140 SARP Thermal chapter, package pressures at NCT and HAC were calculated based on the method described in the previously reviewed Core-Independent M-140 SARP. The Structural chapter indicated that the maximum normal condition internal pressure was less than the allowable pressure analyzed in the bounding Core Independent M-140 SARP.

3.1.4.2 D2W Contents

According to the D2W M-140 SARP Thermal chapter, the calculated pressure within the M-140 package during NCT and HAC considered the partial pressure of gases, vapor pressure of residual water, and potential generation of radiolysis gases from the residual water. The pressure calculation considered steady-state internal temperatures based on an ambient temperature of 100°F (with insolation) and a constant maximum decay heat (i.e., not decreasing over time). As noted in the SARP Thermal and Structural chapters, the calculated steady-state NCT internal pressure within the M-140 shipping container's containment boundary with D2W content, as provided in the D2W M-140 SARP Thermal chapter, was lower than the SARP M-140 container's internal pressure capability.

The previously reviewed Core-Independent M-140 SARP discussed the potential for radiolysis of the residual water within the M-140 shipping container and indicated that measurements have shown the hydrogen concentration from radiolysis would be less than 5 percent by volume.

3.2 Material Properties and Component Specifications

Thermal properties (e.g., thermal conductivity, specific heat, density) of the M-140 packaging and content components were provided in the S6W M-140 SARP Thermal chapter and in the previously reviewed bounding Core-Independent M-140 SARP. The S6W M-140 Thermal chapter provided the thermal analyses' emissivity values for the various surfaces associated with the package, which indicated conservative values were used compared to actual nominal values. In addition, it was stated in the telecon summary (dated August 16, 2022) that the package absorptivity value was 1.

The D2W M-140 SARP Thermal chapter provided package component thermal property values, including for thermal conductivity, specific heat, and density. It indicated properties used in the models accounted for potential uncertainties of 5% to 10%.

As noted earlier, according to the Core Independent M-140 SARP, the Type B package is designed and constructed in accordance with MIL, American Society of Mechanical Engineers, and American National Standards Institute standards and the drawings contained in the SARP.

3.3 Thermal Model Analyses

3.3.1 Normal Conditions of Transport Thermal Model

3.3.1.1 S6W Contents

The S6W M-140 SARP Thermal chapter indicated that the finite element analysis (FEA) ABAQUS code was used to generate a three-dimensional symmetric portion of the railcar structure, M-140 package (e.g., dome, closure head, M-140 vessel), S6W spent fuel modules, and supporting structures. Although fins were not explicitly modeled, their effect on radiation heat transfer and on convection heat transfer by applying a fin effectiveness factor was analyzed using the methodology described in earlier M-140 amendments. The model's convergence acceptance criteria were provided in the thermal chapter. Volumetric heating was applied to the spent fuel module to achieve the decay heat and axial profile. A bounding loading of spent fuel was assumed in the model. Spent fuel temperatures from the FEA code were calculated to ensure acceptable fuel performance criteria were met.

In addition, the S6W M-140 SARP Thermal chapter indicated that a node-based heat transfer code was used to generate a symmetric M-140 package model and a detailed fuel model in order to calculate M-140 package component and fuel temperatures as input for pressure calculation and structural analyses. The boundary conditions were the same as those applied to the ABAQUS FEA model. Symmetry was applied to the package model and the detailed fuel model. The package model included the package's top, bottom, side, and railcar well structure. Although fins were not explicitly modeled, their effect on radiation heat transfer and on convection heat transfer by applying a fin effectiveness factor was analyzed using the methodology described in earlier M-140 amendments. The SARP indicated that small gaps between components included conduction and radiation heat transfer effects whereas large gaps considered radiation heat transfer effects.

The node-based detailed spent fuel model used symmetry to model a spent fuel module. Decay heat was applied as volumetric heating in discrete axial zones of the model. Package temperatures determined from the node-based model described above were applied as boundary conditions at the appropriate locations in the detailed node-based spent fuel model. The details of this model did not change from earlier amendments.

The telecon summary (dated August 16, 2022), indicated that the FEA and node-based package thermal models were used in the previous SARP revisions. For both the node-based models and the FEA model, thermal analyses were based on the package's vertical orientation during NCT. The interior heat transfer modes considered conduction and radiation heat transfer and the exterior considered radiation and convection heat transfer. Specifically, the node-based calculation and the FEA calculation relied on convection heat transfer correlations to model convection. Different heat transfer correlations were applied at different model locations to account for surface orientation. The SARP indicated that the correlation results were reduced by 20 percent to account for uncertainties, except for one correlation that was supported by test results. Areas of the model that would have finned surfaces applied a fin effectiveness factor to the correlation results.

The steady-state thermal calculation for NCT hot conditions was based on 100°F ambient temperature and the effect of insolation during NCT assumed the numerical values associated with flat and curved surfaces described in 10 CFR 71.71(c), but were conservatively applied for a 24-hour period (i.e., not for a 12 hour period). The SARP thermal chapter indicated that the model's heat transfer boundary conditions applied to the package's outer surface finned area considered the increased convection and radiation heat transfer due to the fins, which, as noted earlier, were not explicitly modeled.

3.3.1.2 D2W Contents

According to the D2W M-140 SARP thermal chapter, a three-dimensional FEA model of the M-140 package and fuel assemblies with symmetry boundary conditions was generated. The model included the D2W spent fuel assembly, M-140 fins, body, closure head, cover, dome, the support ring of the railcar used during transportation, and D2W spent fuel assembly details. The SARP noted that conduction heat transfer was considered in solids and small air gaps between components. The air gap between the internal assembly and the M-140 container was modeled assuming conduction and radiation heat transfer. In addition, reduction factors were applied to air gap conductance values. Convection heat transfer correlations were used to determine heat transfer coefficients at external package surfaces. Reduction factors were applied to external heat transfer coefficients to account for uncertainty and boundary layer effects. One of the fuel cells was explicitly modeled and included the regions of the fuel, cladding, and criticality control material and hardware; the remainder of the fuel modules were modeled using homogenous properties. The SARP thermal analysis results indicated that the explicitly modeled fuel cell had higher temperatures (i.e., was bounding) compared to the homogenously modeled fuel module.

The homogenized fuel cell effective thermal conductivity values in the axial, radial, and azimuthal directions were calculated using the thermal resistance in each direction, which considered the internal cell components, including their design, material property, and geometry. The homogenized fuel cell effective density and specific heat values were calculated as a volume average of the components that formed the fuel cell. Although certain geometry-related aspects of the fuel cell design could initially indicate that an effective thermal conductivity property result may not accurately model the overall fuel cell, the relatively close comparison of temperatures between the explicitly modeled fuel cell and the homogenized fuel cell (as noted above) showed the homogenized property inputs for the present model were reasonable.

The D2W M-140 SARP Thermal chapter briefly mentioned a grid sensitivity analysis of different grid refinements. Further discussion in the telecon summary indicated that the acceptance criteria for both the grid sensitivity and timestep sensitivity analyses were approximately 2°F. In terms of energy balances, the telecon summary stated that the amount of energy generated within the model was within 0.03 percent of the applied heat load.

The hot NCT boundary conditions included a 100°F ambient temperature and insolation flux values provided in 10 CFR 71.71(c) with package absorptivity of 1. The insolation was applied to the package's exterior, including the entire finned region that was exposed to the ambient (i.e., not within the railcar structure); insolation was not applied to the unfinned surface between fins because calculations showed only a small percentage of the unfinned area could be exposed to insolation. This assumption was sufficient because the SARP noted that a constant insolation was applied assuming a 24 hour daylight period, which effectively doubled the solar heat load relative to the 10 CFR 71.71 diurnal application (e.g., 12 hour on and 12 hour off).

During the post-fire HAC period, the insolation was applied to the entire area of the finned region since HAC conditions assumed the package was removed from the railcar.

External heat transfer boundary conditions were based on convection correlations for particular package surface orientations. Although these correlations were updated from the correlations used in previous amendments, the telecon summary noted that comparisons of results using both old and new correlations showed similar results. The FEA model did not explicitly model an exterior fluid domain. Therefore, convection correlations for fins, which included reduction factors to account for uncertainties, were applied to the exposed finned regions.

The RAI response submittal presented a comparison table of package temperatures showing the Core Independent M-140 SARP model results bounded adjusted package temperature test data, thereby demonstrating the conservative nature of the Core Independent M-140 SARP model and that the temperatures were appropriate for the structural calculations in the D2W SARP. In addition, the application provided evaluations to show that the new FEA thermal model provided conservative or similar temperatures to previously reviewed thermal models and measurement-related data. For example, the SARP showed the new D2W M-140 FEA thermal model fuel temperatures were greater than test measurement temperatures. In addition, the RAI response submittal provided a comparison of the new FEA model temperatures with the D2W M140 thermal model temperatures in the previous SARP revision; results showed the FEA model temperatures (including the fuel) were conservative, although two components in the FEA model were approximately 1°F lower, which is not significant. Likewise, the temperature of one component was lower in the new FEA model compared to the previous model because of modeling choices for the heat transfer mechanism (i.e., conduction versus convection).

The D2W M-140 SARP, telecon summary, and RAI response submittal indicated that the FEA D2W thermal model included conservative features. For example, the modeled decay heat was conservative relative to actual D2W fuel loadings. In addition, the model did not consider external convection heat transfer in the region between the lower package and railcar and did not consider internal convection heat transfer within the package, whereas the previous model included convection in certain internal gaps, according to the RAI response. Likewise, for a particular package orientation, the model also did not include areas that act as heat removal pathways. As noted earlier, peak insolation values, rather than diurnal values, were applied for the 24 hour period.

The RAI response submittal indicated the fuel temperatures have margin with allowable values even with the FEA model's conservative assumptions. The response noted the margins would be greater if the conservative assumptions were changed to more representative conditions. Likewise, the more representative NCT fuel temperatures (i.e., lower values by removing conservative assumptions) applied as lower initial temperatures for the HAC transient thermal analysis would result in lower peak thermal HAC temperatures than those reported.

3.3.2 Hypothetical Accident Conditions Thermal Model

3.3.2.1 S6W Contents

According to the S6W M-140 SARP Thermal chapter, the node-based and FEA-based NCT models were also used for the HAC fire analyses. The Thermal chapter indicated that the localized damage due to the HAC free drop and puncture tests would have a minor effect on temperatures of the spent fuel within the package (e.g., axial deformations were not in the dominant direction of heat transfer) and, therefore, no changes to the NCT model geometry were included other than assuming the M-140 package was removed from the railcar.

Boundary conditions prior to the HAC fire included solar insolation and a 100°F ambient temperature. Both radiation heat transfer and convection heat transfer over the package periphery were analyzed during the transient fire analysis. The 1475°F fire emissivity was assumed to be 0.9 and the bare package surface absorptivity was assumed to be 0.8, in accordance with 10 CFR 71.73. The radiant heat exchange methodology, including the effect of the fins, between the package and environment was used in earlier S6W M-140 amendment analyses. A forced convection heat transfer coefficient to the package from the hot fire was applied to the bare and finned package surface, with the convection coefficient increased by the fin enhancement factor at the location where fins would be found. After the 30 minute fire, the convection heat transfer coefficients were similar to those used prior to the fire. Solar insolation was applied to the FEA-based HAC model during the cooldown period. The Thermal chapter indicated that insolation was not applied to the node-based HAC model and that the convection heat transfer coefficient during the fire was based on natural convection. Although these two node-based model assumptions were not bounding, the SARP also presented the FEA model results of fuel and package component temperatures and indicated that fuel temperatures for both the node-based and FEA models continued to meet performance criteria.

3.3.2.2 D2W Contents

The D2W M-140 SARP Thermal chapter discussed the 30-minute hypothetical fire accident condition thermal analysis for the M-140 shipping container based on 45,000 Btu/hr for NCT and 46,124 BTU/hr for HAC, decay heat content. The Thermal chapter mentioned that local package damage due to the HAC tests would have a minor effect on fuel temperatures because the direction of package displacements after the HAC tests was not in the direction of the package's predominant heat transfer path; therefore, no changes to the vertical upright NCT model geometry was included other than assuming the M-140 package was removed from the railcar during the fire, thereby exposing the entire package to the 1475°F environment. According to the D2W M-140 SARP Thermal chapter, initial temperatures for the transient analysis were based on steady-state temperatures calculated for hot NCT (e.g., 100°F, with insolation). The 1475°F fire had an emissivity of 1 and the bare package external surface exposed to the fire had a minimum absorptivity of 0.8. The transient included the 30 minute fire condition and subsequent cooldown to a steady-state condition.

The D2W M-140 SARP and telecon summary stated that a sensitivity analysis also included the effect of the M-140 package in a horizontal orientation during the thermal HAC. In this model, a convection correlation was applied to the finned region during the fire. However, no convection heat transfer was assumed during the cooldown period. Unlike the vertical thermal model, the horizontal model assumed a 12 hour insolation (i.e., diurnal) period (rather than a 24 hour insolation period) and additional package structural components, which transfer heat away from the central package region, were included in the model. The vertical orientation resulted in higher temperatures than the horizontal model orientation. Results of the sensitivity analysis indicated fuel temperatures were below allowable values for both orientations.

3.4 Thermal Evaluation Under Normal Conditions of Transport

3.4.1 S6W Contents

As noted earlier, the S6W M-140 SARP Thermal and Structural chapters provided package component and fuel temperatures during the hot NCT conditions. These temperatures were used to confirm that package component temperatures (e.g., seals) were below allowable values and that, as noted in the Containment chapter, the spent fuel cladding remained intact after the NCT tests, which indicated that fuel performance acceptance criteria were met. Thermal stress effects were described in the SARP Structural chapter, which, based on the Core-Independent M-140 SARP, indicated package integrity is not impaired by the effects of differential thermal expansion. The Structural chapter provided the thermal expansion clearances associated with the package and content at normal conditions of transport.

Regarding cold temperatures, the S6W M-140 SARP Structural chapter indicated that structural analyses addressed the minimum cold temperature (-40°F), including the effects of differential thermal contraction and the potential for brittle fracture, and concluded acceptable package performance at the minimum cold temperature. In addition, the Core-Independent M-140 SARP indicated that -40°F is within the allowable temperature range of the M-140 O-ring seals.

The SARP Structural chapter indicated that the maximum normal condition internal pressure was less than the allowable pressure analyzed in the bounding Core-Independent M-140 SARP. In addition, the Core-Independent M-140 SARP indicated that measurements showed that hydrogen concentration from radiolysis would be less than 5 percent by volume.

3.4.2 D2W Contents

The D2W M-140 SARP Thermal and Structural chapters provided package component and fuel temperatures during the hot NCT conditions. As noted earlier, although the Structural chapter indicated that many of the component temperatures had margin with the design temperature values, it also indicated that a few components had reported temperatures slightly above the design temperature. However, the telecon summary indicated that these temperatures were below allowable temperatures; in particular, the seal temperature had sizeable temperature margin with the allowable temperature, as noted in the M-140 Core Independent SARP. RAI responses also noted that the reported temperatures for the components with higher temperatures would be lower and have margin with the design temperature values if the conservative assumption of essentially doubling the insolation effect was reduced, as indicated in the SARP table that compared component temperatures of a model with and without insolation. Therefore, it was noted that the safety impact was maintained. These temperatures were used to confirm that package component temperatures (e.g., seals) were below allowable values and that, as noted in the SARP Containment chapter, the spent fuel cladding remained intact after the NCT tests, which indicated that fuel performance acceptance criteria were met. The SARP Structural chapter indicated that thermal expansion effects were discussed in the Core-Independent M-140 SARP and that there were sufficient clearances in the radial, axial, and tangential directions between the fuel and neighboring structures. Regarding cold temperatures, the D2W M-140 SARP Structural chapter indicated that structural analyses addressed the minimum cold temperature (-40°F), including the effects of differential thermal contraction and the potential for brittle fracture, and concluded acceptable package performance at the minimum cold temperature. In addition, the Core-Independent M-140 SARP indicated that -40°F was within the allowable temperature range of the M-140 O-ring seals.

The D2W M-140 SARP Thermal and Structural chapters indicated that the maximum normal condition internal pressure was less than the allowable pressure analyzed in the bounding Core Independent M-140 SARP. In addition, the Core-Independent M-140 SARP indicated that measurements have shown the hydrogen concentration from radiolysis would be less than 5 percent by volume.

3.5 Thermal Evaluation Under Hypothetical Accident Conditions

3.5.1 S6W Contents

The S6W M-140 SARP Thermal chapter provided the package component and fuel temperatures as a function of time during the HAC fire transient. These temperatures were used to confirm, as noted in the SARP Containment chapter, that fuel performance acceptance criteria were met such that spent fuel cladding remained intact after the HAC fire test. Likewise, these temperatures were used to calculate an internal package pressure based on the methodology described in the Core Independent M-140 SARP. The S6W M-140 SARP Thermal chapter noted that the internal pressure would be below the containment boundary allowable pressure based on maintained seal integrity during HAC. Package pressure would be lower if, as discussed in the SARP Containment chapter, a slight gap formed at the M-140 shipping packaging closure head seating surface after a HAC drop; staff notes that the Containment chapter indicated that containment requirements would continue to be maintained if this slight gap formed. The S6W M-140 SARP Thermal chapter indicated that additional structural effects of the fire accident condition were described in the Core-Independent M-140 SARP.

3.5.2 D2W Contents

The D2W M-140 SARP Thermal chapter provided the package component and fuel temperatures as a function of time during the HAC fire transient. Thermal HAC transient temperature profiles indicated that the fuel temperature did not substantially change from the NCT fuel temperature during the fire and cooldown period, as a result of the package's large thermal inertia. The calculated temperatures confirmed, as noted in the SARP Containment chapter, that fuel performance acceptance criteria were met and that the spent fuel cladding remained intact after the HAC fire test. Likewise, these temperatures were used to calculate an internal package pressure based on the methodology described in the Core-Independent M-140 SARP, such as taking into consideration the non-condensable gases and water vapor. The SARP Thermal chapter noted that the internal pressure would be below the containment boundary allowable pressure for the condition of a containment boundary seal maintaining integrity after the HAC drop.

Finally, the telecon summary indicated that a review of thermal expansion considerations showed that there was positive clearance between the fuel and the container.

3.6 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 with both the S6W and D2W contents meets the thermal requirements in 10 CFR Part 71.

4.0 Containment Evaluation

There were no changes to the package that affect the package containment system for the S6W fuel, therefore, for the S6W fuel, the M-140 package continues to meet the containment requirements in 10 CFR Part 71.

The M-140 spent fuel shipping container is a right circular cylinder that consists of a 14-inch-thick stainless steel forged shell and flange, 12-inch-thick steel bottom plate, and 13-inch-thick stainless steel closure head; multiple pass welds are associated with package and its containment boundary fabrication according to the Core-Independent M-140 SARP. Staff notes that cooling fins are welded to the exterior shell of the package to aid in the passive cooling of the package. The closure head is held in place by a wedge closure system and is sealed using concentric O-rings against the exterior shell flange. The package bottom includes concentric stainless steel rings that act as an energy absorber. The loading and unloading operations of spent fuel are via an access opening in the closure head; the access opening is closed by a bolted shield plug. A stainless steel dome, which is attached to the container body, covers the closure head during transport. Although the M-140 packaging has penetrations for cooling water circulation, venting, and thermocouples, they are not used during transport and are sealed during shipment with plugs and double O-ring seals; therefore, there are no valves and no continuous venting from the packaging. The spent fuel content (e.g., D2W fuel modules) is held in place within the shipping container by an internals-assembly composed of stacked spacer plates. According to the Core Independent M-140 SARP, the Type B package is designed and constructed in accordance with MIL, ASME, and ANSI standards and the drawings contained in the SARP.

The M-140 shipping container was previously reviewed and certified, including for bounding content. The D2W M-140 SARP Acceptance Tests and Maintenance chapter and the Operating Procedures chapter referred to the corresponding chapters in the previously reviewed Core-Independent M-140 SARP. These chapters provide discussion related to leakage rate information. This containment evaluation is based on the SARP addendum for D2W content consisting of the D2W fuel modules and the corresponding internals assembly.

4.1 Description of Content and Containment System

According to the D2W M-140 SARP Containment chapter, the activity of the Type B package is associated with the remaining fissionable material within the spent fuel (e.g., fission products, actinides), irradiated structural components, irradiated corrosion products (crud) that adhere to the surfaces of the fuel module and components, and the irradiated crud deposited on the interior surfaces of the M-140 packaging. The certificate of compliance indicated a number of restrictions associated with D2W shipments of the M-140, such that shipments are restricted to a certain timeframe after reactor shutdown. It is noted that an increased number of days after reactor shutdown would reduce the content's activity, which would favorably affect shielding, containment, and thermal considerations.

According to the D2W M-140 SARP Containment chapter, the spent fuel cladding and weldments are the primary containment of the fuel's remaining fissionable material; the cladding has no penetrations. The D2W M-140 SARP listed a number of acceptance tests associated with the fuel, including ultrasonic testing and radiography. The M-140 packaging acts as the containment boundary for the radioactive content associated with the cladded fuel, irradiated structural components, irradiated crud that adheres to the fuel module surfaces and components, and the irradiated crud deposited on the interior surfaces of the M-140 package.

The M-140 packaging's containment boundary consists of the bottom plate, cylindrical shell, bottom surface of closure head and associated welds as well as double O-ring seals, underside of top plate access plug, and the seals associated with transport container penetrations. Details of the closure and containment boundary are provided in the Core-Independent M-140 SARP and drawings. Likewise, according to the telecon summary (dated August 16, 2022), operating and testing aspects of the package, including leakage rate discussions, were provided in the previously reviewed Core Independent M-140 SARP.

The previously reviewed Core-Independent M-140 SARP discussed the potential for radiolysis of the residual water within the M-140 shipping container and indicated that measurements have shown the hydrogen concentration from radiolysis would be less than 5 percent by volume.

4.2 Containment Under Normal Conditions of Transport

The D2W M-140 SARP Containment chapter indicated that NCT thermal analyses showed fuel temperature limits were met and that fuel cladding remains intact during normal conditions of transport.

Likewise, the D2W M-140 SARP Containment chapter stated that the thermal and structural analyses showed the integrity of the M-140 shipping container containment boundary was maintained for normal conditions of transport and, according to the Core-Independent M-140 SARP, that seal temperatures were within allowable hot and cold temperature range. The D2W M-140 SARP Thermal chapter indicated that the internal pressure of the M-140 package with D2W content was below the pressure assumed for structural analyses.

Based on the fuel cladding integrity and the M-140 containment boundary integrity being maintained during NCT as described above, staff finds that 10 CFR 71.43(f) and 71.51(a)(1) are met.

4.3 Containment Under Hypothetical Accident Conditions

As mentioned in the D2W M-140 SARP Containment chapter, fuel cladding did not fail due to structural-related HAC tests and the high temperatures that can occur as a result of the thermal fire accident condition. Therefore, the integrity of the fuel cladding would be maintained.

However, the D2W M-140 SARP Containment chapter indicated that the structural analyses presented in the Core-Independent M-140 SARP showed that as a result of the HAC tests, a slight gap may form at the M-140 shipping container closure head seating surface. Therefore, the HAC containment analysis for the D2W content was based on demonstrating that certain aspects associated with the D2W content, including the amount of crud and shipping environments, were bounded by the content evaluated in the Core-Independent M-140 SARP that met the containment criteria in 10 CFR 71.51(a)(2) after HAC. For example, the D2W M-140 SARP Containment chapter indicated that the D2W fuel surface area is less than the bounding content surface area, such that there would be less crud compared to the bounding content. Likewise, it was shown that the D2W content and bounding content have consistent coolant chemistry and times between shutdown and shipment, thus indicating the analysis in the Core-Independent M-140 SARP remained valid. In addition, it was stated that the D2W content and the bounding content have similar shipping environments such that the Core-Independent M-140 SARP results are valid for the D2W content. Based on the above, the D2W M-140 SARP Containment chapter stated that because 10 CFR 71.51(a)(2) is met for the bounding content previously reviewed, the regulation also would be met for the D2W content within the M-140 package during HAC.

Based on the above, staff finds that the D2W content within the M-140 package would satisfy 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

There were no changes to the package that affect the package shielding design, therefore the M-140 package continues to meet the dose rate requirements in 10 CFR Part 71.

6.0 Criticality Evaluation

There were no changes to the package that affect the package criticality design, therefore the M-140 package continues to meet the fissile material requirements in 10 CFR Part 71.

7.0 Materials Evaluation

The staff reviewed Revision 6 to the S6W Spent Fuel in the M-140 SAR, to verify that the material performance of the S6W spent fuel in the M-140 packaging meets the requirements of 10 CFR Part 71. Only the sections of the materials evaluation that changed from the previous SARs will be discussed below.

7.1 Materials of Construction

The applicant submitted a revision to the SARP, to demonstrate the material adequacy of a revised S6W grapple adapter design. The grapple adapter, attached to the top of the manifold of each fuel module, is used for removal of the fuel modules from the M-140 package and to prevent control rod withdrawal during normal and accident shipping conditions. The grapple adapter assembly consists of a body, rotation, plate, lifting hub, cap screws, and locking hardware. The body, rotation plate, and four socket head cap screws are made of Nitronic 60. The lifting hub is made of annealed Nitronic 50. Per the above discussion, the staff finds that the applicant's description of the materials of construction to be acceptable.

7.2 Drawings

The applicant provided new drawings (figures 1.3-79 through 1.3-84) in appendix 1.3.2 of the SAR to incorporate the new S6W grapple adapter body, lock, rotation plate, and lifting hub. The drawings include a parts list that provides the material specification of each component, and they also provide the welding and examination requirements. The staff notes that the level of detail in the new drawings are consistent with those of the previously approved drawings. The staff reviewed the drawing content with respect to the guidance in NUREG-2216 Section 7.4.1, "Drawings" and NUREG/CR-5502, "Engineering Drawings for 10 CFR Part 71 Package Approvals." The staff confirmed that the drawings provide an adequate description of the materials, fabrication, and examination requirements. Therefore, the staff finds the drawings to be acceptable.

7.3 Codes and Standards

The grapple adapter design largely adopts MIL standards, including those of the Naval Nuclear Propulsion Program. Additionally, codes and standards of ASTM International (ASTM) are also adopted. The staff finds the codes and standards acceptable because the use of MIL and ASTM standards is consistent with the guidance in NUREG-2216 for important to safety components that do not comprise the containment boundary.

7.4 Material Properties

The new drawings in appendix 1.3.2 reference ASTM standard materials, including stainless steels. The staff reviewed the mechanical and thermal properties provided in table 2.3-1 and verified that they are consistent with the standards for materials listed above. In addition, the staff verified that appropriate testing was performed to ensure that the structural materials have sufficient fracture toughness. The staff also verified that the melting points of materials are demonstrated to be sufficiently high for the intended application. Therefore, the staff finds the material properties to be acceptable.

7.5 Corrosion Resistance and Content Reactions

The staff reviewed the revision changes and verified that they do not introduce any adverse corrosive or other reactions that were not previously considered in the staff's prior review of the M-140 package. The materials of construction and the service environments are bounded by those that were previously evaluated in the certificate of compliance. Therefore, the staff finds the applicant's evaluation of corrosion resistance and potential adverse reactions to be acceptable.

7.6 Evaluation Findings

F7.1 The applicant has met the requirements in 10 CFR 71.33. The applicant described the materials used in the transportation package in sufficient detail to support the staff's evaluation.

F7.2 The applicant has met the requirements in 10 CFR 71.43(f) and 10 CFR 71.51(a). The applicant demonstrated effective materials performance of packaging components under normal conditions of transport and hypothetical accident conditions.

F7.3 The applicant has met the requirements in 10 CFR 71.55(d)(2). The applicant has demonstrated that the package will be designed and constructed such that the analyzed geometric form of its contents will not be substantially altered and there will be no loss or dispersal of the contents under the tests for normal conditions of transport.

The staff concludes that Revision 6 to the grapple adaptor for the S6W spent fuel in the M-140 shipping packaging SAR adequately considers material properties and material quality controls such that the design is in compliance with 10 CFR Part 71. This finding is reached on the basis of a review that considered the regulation, itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

8.0 Operating Procedures

There were no changes to the package that affect the operating procedures, therefore the M-140 package continues to meet the containment requirements in 10 CFR Part 71.

9.0 Acceptance Tests and Maintenance Program

There were no changes to the package that affect the acceptance tests or maintenance program therefore the M-140 package continues to meet the containment requirements in 10 CFR Part 71.

CONDITIONS

The following changes have been made to the certificate:

Condition 5b.(2)(iv) was revised to use a single package decay heat for all shipments.

The “REFERENCES” section was revised to include the date of the supplement to application. The renewal application date of March 23, 2021, was already added as a reference in the last revision since the letter was both a renewal and amendment.

CONCLUSION

These changes do not affect the ability of the package to meet the requirements of 10 CFR Part 71.

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