Safety Evaluation Report
Docket No. 71-9793
Model No. M-140 Package
Certificate of Compliance No. 9793
Revision No. 20

Summary

By letters dated March 23, 2021, (Agencywide Documents Access and Management System [ADAMS] Accession No. ML21105A528) and August 26, 2021 (ADAMS Accession No. ML21244A483), as supplemented on April 1, 2022 (ADAMS Accession No. ML22166A008), and April 29, 2022 (ADAMS Accession No. ML22166A056), 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 approval of the S3G-3 reactor cores installed in both Moored Training Ship (MTS), the Daniel Webster and Sam Rayburn.

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 staff reviewed the application (References 1 and 2), which include the updated S3G-3 SAR and an addendum to the safety analysis report (SAR), Revision 16 for DOE-NR Certificate of Compliance (CoC) USA/9793/B(U)F-85 to ship the S3G-3 spent fuel modules in the M-140 spent fuel shipping container, to verify that the structural performance of the package meets the requirements of 10 CFR Part 71.

2.1 Structural Design

The M-140 spent fuel shipping container (herein referred to as the M-140 container) is certified as a Type B package for shipment of fissile and highly radioactive material. The M-140 container has an S3G-3 internal component, which is designed to accommodate only the S3G-3 fuel modules.

The applicant, Naval Reactors, stated that a S3G-3 reactor core is installed in a MTS, which will be deactivated in 2022. However, the S3G-3 fuel modules installed in the MTS (herein referred to as the MTS S3G-3 modules) have a minor difference in the upper fuel module structure from the previous S3G-3 fuel modules, which were reviewed and approved by the staff in using Reference 1. As a result, the applicant submitted an application as an addendum to the S3G-3 SAR (Reference 2). The addendum contains only the additional structural analyses to demonstrate the structural design adequacy of the MTS S3G-3 modules under both NCT and HAC, as required by 10 CFR Part 71.

The staff notes that the application did not contain any additional structural analyses for the MTS S3G-3 modules if they were already evaluated or bounded by the structural analyses of the previous S3G-3 modules provided in the S3G-3 SAR.

2.1.1 Description of Structures

The M-140 container is a right circular cylinder stainless steel structure and is made of four principal structural components: (i) container body, (ii) closure head, (iii) protective dome, and (iv) S3G-3 internal, which holds the fuel modules in place. The major structural components of the S3G-3 internal in the M-140 container are the spacer plates, the top and bottom spring plates, the top plate assembly, and cell index plate, the support cylinder and the springs. The applicant provided the dimensions and weights of the MTS fuel module in Table A.1-2 of Chapter A.1, “General Information,” of the application. In addition, the applicant provided the design drawings with detailed information in Appendix A.1.3.2, “Design Drawings,” of the application to demonstrate compliance with 10 CFR 71.33(a)

The staff reviewed the structural descriptions and drawings for completeness and accuracy, and finds that the geometry, dimensions, materials, components, notes and fabrication details were adequately incorporated in the application.

2.1.2 Design Criteria

The design criteria used to evaluate the MTS S3G-3 module are identical to the design criteria used for the evaluations of the previous S3G-3 module, as documented in Section 2.1.2, “Design Criteria,” of the SAR (Reference 1). There are no changed or proposed design criteria in the application for the NCT and HAC evaluations.

The staff finds that the structural design criteria for the MTS S3G-3 module are acceptable because the design of the MTS S3G-3 contents is similar to the design of the previous S3G-3 contents (i.e., loads, weights, dimensions, configurations, materials, etc.), and those structural design criteria, analyses and designs of the previous S3G-3 contents were reviewed and accepted by the staff.

2.2 Weights and Centers of Gravity

The nominal weights and locations of the center of gravity (CG) of the M-140 package components are provided in Table A.2.2-1 of the application. These weights and CG are used for the structural evaluations to meet the NCT and HAC requirements of 10 CFR Part 71. The staff reviewed the information and determined that the applicant provided adequate information to describe the weights and determine the CG.

2.3 General Requirements for All Packages

2.3.1 Minimum Packaging Size

The smallest overall dimension of the M-140 package is larger than the minimum requirement of 4.0 inches in 10 CFR 71.43(a).

The staff determined that the application meets the regulatory requirement of 10 CFR 71.43(a).

2.3.2 Tamper-Indicating Features

There is no design change proposed for the M-140 package in the application. The tamper-indicating features of the M-140 package, which were previously reviewed and approved by the staff, are still valid for the M-140 package with the MTS S3G-3 contents.

The staff determined that the application meets the regulatory requirements of 10 CFR 71.43(b).

2.3.3 Positive Closures

There is no design change proposed for the M-140 container in the application. The positive closures of the M-140 package, which were previously reviewed and accepted by the staff, are still valid for the MTS S3G-3 contents.

The staff determined that the application 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 M-140 package meets the requirements of 10 CFR 71.45(a) and 71.45(b) for lifting devices and tie-down standards, respectively, because: (i) there is no design change proposed for the M-140 packaging, and (ii) the locations of the center of gravity of the M-140 package with the MTS S3G-3 contents and the previous S3G-3 contents in the updated S3G-3 SARP are within the acceptable range.

The staff determined that the application meets the regulatory requirements of 10 CFR 71.45(a) and 71.45(b).

2.5 Normal Conditions of Transport

The applicant indicated that evaluations for the structural components of the M-140 package under NCT are not repeated in the application because: (i) the structural components of both the MTS S3G-3 contents and the previous S3G-3 contents in the M-140 package are similar to each other, and (ii) the loading conditions of the structural components are similar except the maximum pressure, where the calculated maximum pressure with the MTS contents inside the M-140 container during the NCT is 31.5 psig, while the maximum pressure of 75.0 psig was previously used to analyze the M-140 container during the NCT in Reference 3.Therefore, the structural performance of the M-140 container when subjected to 75.0 psig bounds the structural performance when subjected to 31.5 psig. The detailed evaluations for the pressures and temperatures are provided in Chapter 3.0, "Thermal Evaluation," of this SER.

The staff agrees with the applicant's conclusion and finds it to be acceptable because the structural performance of the previous S3G-3 contents when subjected to 75.0 psig, which was previously reviewed and accepted by the staff, can be applicable and bounds the structural performance of the MTS S3G-3 package when subjected to 31.5 psig.

The staff determined that the MTS S3G-3 in the M-140 package satisfies the regulatory requirements of 10 CFR 71.71.

2.6 Hypothetical Accident Conditions

The applicant evaluated the M-140 package for HAC of free drop, thermal, and water immersion as required by 10 CFR 71.73. However, structural evaluations for HAC of crush and puncture were not performed because the evaluations of the previous S3G-3 contents in the M-140 package provided in the updated S3G-3 SARP are still valid for the MTS S3G-3 contents.

The applicant analyzed the M-140 package using the closed-form solutions and a computer program, CRUSHTAB, which were used for the evaluations of the previous S3G-3 contents in the M-140 packaging in the application to demonstrate compliance with the regulatory requirements for HAC in 10 CFR 71.73. The CRUSHTAB program was developed to determine the impact deformations and the center-of-mass decelerations of the structural components in a shipping container impacting on an unyielding surface for free drops (flat end, flat side and corner drops). The staff previously reviewed and approved the package design based on the adequacy of using the CRUSHTAB program for drop analyses in Reference 3.

2.6.1 Free Drop

The regulations in 10 CFR 71.73(c)(1) requires that a package needs to be demonstrated for structural adequacy by a free drop through a distance of 30 feet 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 MTS S3G-3 modules in the M-140 packaging for impact orientations in which the package strikes the impact surface. The applicant considered five drop configurations: (i) flat top drop, (ii) top corner drop, (iii) side drop, (iv) bottom corner drop, and (v) flat bottom drop.

The results of the drop analyses using the CRUSHTAB program for the structural components of the MTS S3G-3 modules are provided in Appendices A.2.10.2 through A.2.10.5 of the application. The results of the top drop analyses for the MTS S3G-3 fuel cells in the M-140 packaging show that the fuel cluster in the fuel cells was undamaged. The results of the side drop analyses for the MTS S3G-3 fuel cells in the M-140 packaging show that the cell housings and the fuel clusters remain elastic, which indicates that the primary containment is maintained. Additionally, the results of the bottom drop analyses for the MTS S3G-3 fuel cells in the M-140 packaging show that the bottom energy fuel observers prevent yielding in the fueled region, which indicates that the primary containment is maintained.

The staff reviewed the results of the CRUSHTAB analyses presented in Appendices A.2.10.2 through A.2.10.5 of the application, and, based on its reviews and verifications, the staff confirmed the applicant's findings.

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

2.6.2 Thermal

The regulations in 10 CFR Part 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 MTS S3G-3 package under HAC in Chapter A.3, "Thermal Evaluation," of the application. The following results are from a summary of the applicant's thermal evaluations in Chapter 3 of the application: (i) there is no degradation of the sealing capability of the containment system, (ii) all calculated stresses are less than the allowable stresses, (iii) the fire condition does not affect the safety of the package, (iv) there is no loss of radioactive material, and (v) the primary containment of the MTS spent fuel will be maintained under HAC.

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

2.6.3 Immersion – Fissile Material

The regulations in 10 CFR Part 71.73(c)(5) requires that for fissile material subject to 10 CFR Part 71.55, in those cases where water in-leakage has not been assumed for criticality analysis, it must be evaluated for immersion under a head of water of at least 3 feet in the attitude for which maximum leakage is expected.

The applicant stated that detailed criticality analyses for the M-140 package containing the MTS S3G-3 fuel modules under HAC are provided in Chapter A.6, "Criticality Evaluation," of the application, where the criticality analysis considered water in-leakage. Based on the results of the criticality analyses in Chapter A.6, the applicant made a conclusion that the M-140 package and its MTS S3G-3 contents will remain subcritical under the worst-case condition of preferential flooding and control rod withdrawal. Therefore, the M-140 package is acceptable under immersion conditions.

The staff reviewed the analyses and found it acceptable because the application evaluated the criticality analysis under the assumption that the M-140 package containing the MTS S3G-3 modules assuming in-leakage of water. The staff's reviews and safety evaluations on the applicant's criticality evaluations are provided in Chapter 6 of this SER.

The staff determined that the application satisfies the regulatory requirements of 10 CFR 71.73(c)(5).

2.7 Special Form

This section is not applicable to the M-140 package. This application does not seek approval for transport of special form radioactive materials and, therefore, the requirements of 10 CFR 71.75 are not evaluated.

2.8 Fuel Cladding

The fuel cladding is relied upon to provide the primary containment boundary for nuclear fuel. The applicant stated that the structural analyses provided in Chapter 2 (Reference 2) and Chapter A.2 of the application (Reference 1) and thermal analyses provided in Chapter 3 (Reference 2) and Chapter A.3 of the application (Reference 1) show that integrity of the fuel cladding is maintained under NCT and HAC.

As discussed above, the staff reviewed the results of the structural evaluations in Chapters 2, A.2, 3 and A.3 of the SARPs (References 1 and 2) and found that the fuel cladding of the MTS S3G-3 modules in the M-140 packaging is not vulnerable to failure (rupture or breach) under HAC. Additional safety evaluations with respect to the fuel cladding integrity during NCT and HAC thermal tests are provided in Chapter 3 of this SER.

2.9 Evaluation Findings

Based on a 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 MTS S3G-3 modules in the M-140 transportation packaging have adequate structural integrity to meet the structural requirements of 10 CFR Part 71.

2.10 References

1. WAPD-REO(C)-1395 – S3G-3 Spent Fuel in the M-140 Safety Analysis Report for Packaging.

2. WAPD-REO(C)-1395 – MTS Spent Fuel in the M-140 Safety Analysis Report for Packaging Addendum.

3. WAPD-REO(C)-1600 – Core Independent M-140 Safety Analysis Report for Packaging.

3.0 Thermal Evaluation

3.1 Description of Thermal Design

3.1.1 Design Features

The M-140 spent fuel shipping container includes a right circular cylindrical shell that is a 14-inch thick stainless steel forging with flange, 12-inch thick steel bottom plate, 13-inch thick stainless steel closure head and is fabricated with multi-pass welds according to the Core-

Independent SARP. Cooling fins are welded to the exterior shell of the shipping container 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 cask 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 package 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 shipping container. The spent fuel content (e.g., MTS S3G-3 fuel modules, bounding S3G-3 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 Military Specifications, American Society of Mechanical Engineers, and American National Standards Institute standards and the drawings contained in the SARP.

The M-140 package was previously reviewed and certified, including for the bounding S3G-3 content. The MTS S3G-3 M-140 SARP's Acceptance Tests and Maintenance chapter and the Operating Procedures chapter referred to the corresponding chapters in the previously reviewed Core-Independent M-140 SARP. This thermal evaluation is based on the SARP addendum for MTS S3G-3 content (a type of S3G-3 fuel module) consisting of the MTS S3G-3 fuel modules and the internals assembly. As noted in the MTS S3G-3 addendum M-140 SARP and the application letter, the MTS S3G-3 content has minor differences compared to the approved S3G-3 contents and is bounded by the previous evaluations associated with the Core-Independent M-140 SARP and the bounding S3G-3 M-140 SARP.

3.1.2 Content Decay Heat

According to the MTS S3G-3 M-140 SARP's Containment chapter, 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 module 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 shipping container acts as a containment boundary for the package's internal components and irradiated crud. The SARP's thermal analyses were based on a decay heat value (62,300 Btu/hr) that was reported in the previously reviewed bounding S3G-3 content, which, according to the S3G-3 M-140 SARP, has margin relative to the fuel's actual decay heat. The SAR associated with the MTS S3G-3 contents stated that draining of the M-140 shipping container would not occur until content decay heat was at or below 62,300 Btu/hr.

3.1.3 Summary of Temperatures

The maximum temperature of the accessible surface of a M-140 package with S3G-3 cargo (e.g., MTS S3G-3 content) at hot NTC and maximum decay heat, as presented in the bounding S3G-3 M-140 SARP Thermal chapter, showed a temperature that was greater than the 122°F regulatory limit for non-exclusive use shipment, but less than the 185°F regulatory limit for exclusive use shipment described in 10 CFR 71.43(g).

The bounding S3G-3 M-140 SARP Structural chapter listed the temperatures of package components (e.g., container's closure head and seal, container internals, and fuel modules) and showed that the temperatures used for structural calculations were larger or equal to those calculated in the hot NCT thermal analyses in the SARP Thermal chapter, thus indicating there were bounding thermal effects with the structural analyses. Likewise, the Core-Independent M-140 SARP indicated that the M-140 O-rings seals were within the seals' allowable temperature range. The MTS S3G-3 M-140 SARP Thermal chapter showed that fuel temperatures were below allowable values during the HAC fire.

Regarding cold temperatures, the bounding S3G-3 M-140 SARP Structural chapter analyzed the impact of critical components at cold temperatures and indicated that the package could meet its performance functions at -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.

According to the MTS S3G-3 M-140 SARP's Structural chapter and Thermal chapter, the package temperatures associated with NCT were within allowable temperatures. Likewise, the SARP's Structural and Thermal chapters indicated that results from the HAC numerical analysis showed that fuel cladding temperatures were within allowable temperatures and that fuel cladding integrity would be maintained.

3.1.4 Summary of Maximum Pressures

According to the MTS S3G-3 M-140 SARP's Thermal and Containment chapters, the calculated pressure within the M-140 shipping container 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; staff notes that the Core-Independent M-140 SARP indicated that measurements have shown hydrogen concentrations from radiolysis are less than 5% by volume. The pressure calculation considered internal temperatures based on an ambient temperature boundary condition of 100°F (with insolation) and a constant maximum decay heat (i.e., not decreasing over time). According to the MTS S3G-3 M-140 SARP's Structural and Containment chapters, the internal pressure within the fuel cladding from fission gases at the fuel's maximum decay heat during NCT did not adversely affect the cladding integrity. Staff found that the calculated steady-state NCT internal pressure within the M-140 shipping container's containment boundary with MTS S3G-3 content, as provided in the MTS S3G-3 M-140 SARP Thermal chapter, was less than the internal pressure associated with the bounding M-140 S3G-3 content mentioned in the S3G-3 SARP as well as the bounding M-140 content described in the Core Independent M-140 SARP. In addition, the S3G-3 SARP indicated that the cladding integrity was maintained during HAC and the M-140 shipping container's containment boundary could withstand internal pressures for a package exposed to an 800°C fire for 30 minutes. The bounding S3G-3 M-140 SARP's Structural chapter noted that the stresses associated with the pressures during NCT and HAC for the fire test were below the bounding pressure analyzed for package design.

3.2 Material Properties and Component Specifications

The MTS S3G-3 M-140 SARP Thermal chapter indicated that the thermal properties for the M-140 container with the MTS S3G-3 cargo were the same as those found in the previously reviewed bounding S3G-3 M-140 SARP. The MTS S3G-3 M-140 SARP Thermal chapter described a sensitivity analysis to determine the impact of a 5% reduction in the thermal conductivity and specific heat material of the package's properties and found less than 15°F difference in package and content temperatures compared to nominal values; the SARP noted that this increase in temperature was added to previous results and the updated temperatures continued to be below allowable values.

3.3 Thermal Evaluation Under Normal Conditions of Transport

According to the bounding S3G-3 M-140 SARP and MTS S3G-3 M-140 SARP, there was an NCT thermal analysis associated with the M-140 shipping container and a separate thermal analysis associated with the fuel module. The MTS S3G-3 M-140 SARP Thermal chapter stated that the NCT M-140 shipping container thermal analysis and results presented in the bounding S3G-3 M-140 SARP continue to be valid for the MTS S3G-3 cargo; this is because the decay heat for the MTS S3G-3 content is not greater than the bounding S3G-3 content, and the fuel assemblies are sufficiently similar to have the same heat transfer characteristics. For the MTS S3G-3 M-140 model, the thermal calculation for NCT hot conditions was based on 100°F ambient temperature and the effect of insolation during NCT, which 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 (not for a 12-hour period). The heat transfer boundary conditions applied to the outer surface of the model considered the increased convection and radiation heat transfer due to the fins, which were not explicitly modeled.

Although the MTS S3G-3 M-140 SARP thermal chapter indicated that the bounding S3G-3 M-140 SARP's NCT (and HAC) thermal models and results (e.g., pressure, temperatures, fuel temperatures) were valid for the MTS S3G-3 contents, the MTS S3G-3 M-140 SARP's Thermal chapter discussed a new fuel module NCT thermal model, which was based on finite element software. The three-dimensional model considered an interior 360 degree portion of the package that included the fuel module, adjacent hardware, and the internals assembly that holds the fuel. The axial extent of the model was the portion associated with the height of the fuel decay heat source and some distance above and below the fuel region. The decay heat of a fuel module was modeled by applying a volumetric heat source at discrete locations where fuel was located within the fuel module. The boundary condition temperatures applied to the internals assembly were based on the NCT M-140 shipping container model results (mentioned above and described in the bounding S3G-3 M-140 SARP). The MTS S3G-3 M-140 SARP Thermal chapter noted that modeling of the gaps between the fuel and the internal-assemblies considered one-dimensional conduction and radiation. The MTS S3G-3 M-140 SARP Thermal chapter indicated that the M-140 model results in the S3G-3 SARP remain applicable to the MTS S3G-3 content. The new fuel model results showed cladding temperature was below allowable values and pressure was below the pressure in the bounding S3G-3 SARP analysis.

Additional information about the NCT and HAC thermal models was presented in the response to a request for additional information dated April 29, 2022. Specifically, the response discussed a comparison between the new NCT thermal model and the new HAC thermal model's initial condition results to prototypic M-140 container thermal test data and showed the computational models' results were conservative relative to the presented test data. In addition, the RAI response included examples and discussion showing that, although the new NCT and HAC thermal models have greater model fidelity which reduces some of the previous models' conservatisms, they continue to have conservative modeling features that result in margin to the fuel and package component temperature acceptance criteria. The response also stated that the new model's energy balance was within 1%.

The bounding S3G-3 SARP's Structural chapter indicated there was no damage to the package during NCT due to stresses from thermal expansions and pressures. Likewise, the MTS S3G-3 M-140 SARP's Structural and Thermal chapters indicated that the fuel cladding integrity was maintained under NCT and HAC.

3.4 Thermal Evaluation Under Hypothetical Accident Conditions

The MTS S3G-3 M-140 SARP's Thermal chapter discussed the thermal analysis for the 30-minute HAC fire test for the M-140 package with 62,300 Btu/hr decay heat content. The bounding S3G-3 M-140 SARP thermal chapter indicated there was no substantial damage to the M-140 package after the HAC drops and puncture that warranted inclusion in the HAC thermal model; for example, the steel dome that covers the closure head during transport remained attached to the container body.

As noted earlier, although the thermal results reported in the previously reviewed S3G-3 M-140 SARP were valid for the MTS S3G-3 content, the MTS S3G-3 M-140 SARP Thermal chapter described a new HAC thermal model. The extent of the three-dimensional, finite-element model included a wedged portion of the M-140 shipping container, fuel with hardware, and internals assembly. The axial extent of the model included the fuel region that produced the decay heat and an area slightly above and below it; the SARP Thermal chapter indicated that the reduced axial domain results in higher fuel and package temperatures. The MTS S3G-3 M-140 SARP's Thermal chapter noted that the effect of the rail car on the model was included prior to the HAC fire condition for determining initial package conditions but then was removed during and after the 30-minute hypothetical fire to represent the HAC modeled condition of an upright shipping container exposed to the fire. The MTS S3G-3 M-140 SARP also stated that a sensitivity analysis of the M-140 at a different orientation during the HAC fire was analyzed with results indicating fuel temperatures were below allowable values for both orientations. In addition, the MTS S3G-3 M-140 SARP's Thermal chapter noted that, although the gap between the shipping container and adjacent structures varies during and after the HAC fire due to thermal expansion and contraction, a sensitivity analysis using the new thermal HAC model confirmed the changing gap conductance had minimal impact on results.

According to the MTS S3G-3 M-140 SARP Thermal chapter, initial temperature conditions for the transient analysis were based on steady-state temperatures calculated for hot NCT (e.g., 100°F, with insolation). The Thermal chapter indicated that the calculated HAC initial conditions associated with the new HAC thermal model were similar to the calculated NCT fuel temperatures with the new NCT fuel thermal model described earlier. The 1475°F fire had an emissivity of 0.9, the bare package exterior surface exposed to the fire had an absorptivity of 0.8, and the M-140 package's finned surface exterior (fins were not explicitly modeled) emissivity values accounted for fin effects. The MTS S3G-3 M-140 SARP Thermal chapter indicated that thermal conductivity and specific heat properties were reduced by up to 10% and that convection coefficients were reduced by 25%; these reductions were applied to account for uncertainties associated with the correlation and the fin performance. Results presented in the MTS S3G-3 M-140 SARP Thermal chapter and bounding S3G-3 M-140 SARP Thermal chapter indicated the peak fuel temperature for the HAC fire is less than the acceptance criterion allowable temperature. The MTS S3G-3 M-140 SARP Thermal chapter also indicated that both grid sensitivity and time step sensitivity analyses were performed to ensure adequate spatial and temporal resolution; results showed less than 1°F temperature variations. The S3G-3 M-140 SARP indicated that the M-140 pressure based on a maintained seal integrity during the HAC fire condition was below the analyzed pressure in the Core-Independent M-140 SARP. The MTS S3G-3 M-140 SARP Thermal chapter indicated that M-140 thermal stresses were addressed in the Core-Independent M-140 SARP.

The MTS S3G-3 M-140 SARP Thermal chapter compared the cladding temperature transient HAC fire profiles, including during the cooldown period, of the previous thermal analysis and the new thermal analysis. The figure showed that both models had similar profiles, but that the cladding temperatures from the new thermal analysis were less. Staff finds that the lower temperatures are expected, as the new model more accurately represents the package geometry, thereby removing some bounding aspects and conservative modeling practices found in the old model; the conservative aspect of the HAC thermal model was mentioned in the NCT thermal model discussion, above. The MTS S3G-3 M-140 SARP Thermal chapter and Structural chapter indicated that fuel temperature was below HAC allowable values and that the fuel cladding integrity is maintained under HAC.

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 M-140 spent fuel shipping container is a right circular cylinder that consists of 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 the shipping container and containment boundary fabrication according to the Core-Independent M-140 SARP. Staff notes that cooling fins are welded to the exterior shell of the shipping container 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 cask 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 package 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 shipping container. The spent fuel content (e.g., MTS S3G-3 fuel modules, bounding S3G-3 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 Military Specifications, American Society of Mechanical Engineers, and American National Standards Institute standards and the drawings contained in the SARP.

The M-140 package was previously reviewed and certified, including for the bounding S3G-3 content. The MTS S3G-3 M-140 SARP's Acceptance Tests and Maintenance chapter and the Operating Procedures chapter referred to the corresponding chapters in the previously reviewed Core-Independent M-140 SARP. This containment evaluation is based on the SARP addendum for MTS S3G-3 content consisting of the MTS S3G-3 fuel modules and the corresponding internals assembly. As noted in the MTS S3G-3 addendum M-140 SARP and the application letter, the MTS S3G-3 content has minor differences compared to the approved S3G-3 content and is bounded by the previous evaluations associated with the Core-Independent M-140 SARP and the S3G-3 M-140 SARP.

4.1 Description of Content and Containment System

According to the MTS S3G-3 M-140 SARP's 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 container. Activity of content was provided in the S3G-3 M-140 SARP. The MTS S3G-3 M-140 SARP's Containment chapter noted that package activity is bounded by the content associated with the Core Independent M-140 SARP. The CoC notes a number of restrictions associated with shipments of the M-140, including the following: shipments are not to made earlier than 120 days after shutdown for shielding considerations, container draining shall not occur earlier than 130 days after reactor shutdown for thermal considerations, and shipments shall not be made earlier than 150 days after shutdown for containment considerations. 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 MTS S3G-3 M-140 SARP's Containment chapter, the spent fuel cladding and weldments contain the fuel's remaining fissionable material; the cladding has no penetrations. The MTS S3G-3 M-140 SARP listed a number of acceptance tests associated with the fuel, including ultrasonic testing and radiography. The M-140 shipping container 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 container. The M-140 shipping container's containment boundary consists of the shipping container's 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. The S3G-3 M-140 SARP noted that details of the closure and containment boundary are provided in the Core-Independent SARP and drawings.

The previously reviewed Core-Independent M-140 SARP discussed the potential for radiolysis of the residual water within the M-140 shipping container. As noted in the SER Thermal evaluation, the potential for radiolysis gases was considered in the pressure calculations. Likewise, the Core-Independent M-140 SARP indicated that measurements have shown hydrogen concentrations from radiolysis are less than 5%.

4.2 Containment Under Normal Conditions of Transport

The MTS S3G-3 M-140 SARP's Containment chapter stated that there is no release of content during NCT because the thermal analyses indicated that fuel temperature limits are met, fuel cladding stresses were below allowable values, and fuel cladding integrity was not affected by the internal pressure from the MTS S3G-3 spent fuel fission gases.

Likewise, the MTS S3G-3 M-140 SARP's Containment chapter stated that the thermal and structural analyses showed the integrity of the M-140 shipping container containment boundary was maintained for NCT and, according to the Core-Independent M-140 SARP, that seal temperatures were within allowable hot and cold temperature range. The MTS S3G-3 M-140 SARP Containment chapter also mentioned that the internal pressure of the M-140 shipping container with MTS S3G-3 content is bounded by the internal pressure associated with the previously reviewed bounding S3G-3 content analysis and the Core-Independent M-140 analysis.

The MTS S3G-3 M-140 SARP Containment chapter indicated that seal leakage rate tests per American National Standards Institute N14.5-2014 (Reference 1) requirements are performed when shipping MTS S3G-3 content to ensure the 10 CFR 71.51(a)(1) regulatory requirement of no dispersal at NCT is met (as demonstrated to a sensitivity of 1E-6 A_2/hr); details of the tests were referenced in the Core-Independent M-140 SARP.

Based on the fuel cladding integrity and the M-140 shipping container containment boundary integrity being maintained during NCT as described above, and the inclusion of leakage tests described in the previously reviewed Core-Independent M-140 SARP, staff finds that 10 CFR 71.43(f) and 71.51(a)(1) are met.

4.3 Containment Under Hypothetical Accident Conditions

According to the MTS S3G-3 M-140 SARP's Containment chapter, fuel cladding does not fail due to the high temperatures that occur as a result of the thermal fire accident condition and the structural calculations showed that the fuel cladding's stresses during HAC are below allowable values. Therefore, the integrity of the fuel cladding would be maintained.

However, the MTS S3G-3 M-140 SARP Containment chapter indicated that the structural analyses presented in the Core-Independent M-140 SARP showed that under a HAC drop test, a very slight gap may form at the M-140 shipping container closure head seating surface. Therefore, the HAC containment analysis for the MTS S3G-3 content was based on demonstrating that certain aspects associated with the MTS S3G-3 content, including the amount of crud and shipping environments, were bounded by previously approved content described in the Core-Independent M-140 SARP that had met the regulatory limits at HAC. For example, the MTS S3G-3 M-140 SARP Containment chapter indicated that the MTS S3G-3 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 MTS S3G-3 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 MTS S3G-3 content and the bounding content have similar shipping environments (e.g., temperature and pressure) such that there would be no significant difference due to MTS S3G-3 content and that the Core-Independent M-140 SARP results were appropriate. Based on the above, the MTS S3G-3 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 MTS S3G-3 content within the M-140 shipping container during HAC.

Based on the above, staff finds that the MTS S3G-3 content within the M-140 shipping container 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.

4.5 References

1. American National Standards Institute, ANSI N14.5-2014, "Radioactive Materials—Leakage Tests on Packages for Shipment," New York, NY.

5.0 Shielding Evaluation

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

6.0 Criticality Evaluation

The applicant requested an amendment to the certificate for the M-140 package, with the only change related to the criticality evaluation was the revised S3G-3 spent fuel characteristics for the MTS S3G-3 contents. The objective of this review is to verify that the M-140 shipping container continues to meet the criticality safety requirements of 10 CFR Part 71 under normal conditions of transport and hypothetical accident conditions.

6.1 Description of Criticality Design

The applicant has proposed no significant changes to the packaging and the systems, structures and components relied upon for criticality safety remain unchanged from the previously approved revision.

6.2 Fissile Material Contents

The applicant has proposed to add MTS S3G-3 type fuel modules. These modules have a slight difference in the upper structure from previously approved S3G-3 spent fuel modules.

6.3 General Considerations for Criticality Evaluations

The applicant used the same Monte Carlo code in its criticality evaluation as in prior, NRC-approved revisions. The applicant used a new cross-section library based on standard evaluated nuclear data files which staff has found acceptable in other criticality evaluations. The applicant’s modeling assumptions are either unchanged or more conservative than in the previous revision. The applicant chose a core effective full power hour that is at the minimum of a range where increasing burnup results in decreased fuel reactivity. Staff finds the applicant’s changes acceptable since they both will result in a higher calculated reactivity. With these conservative modeling assumptions, the applicant’s results show a maximum reactivity is lower than the previously approved contents. For these reasons, staff finds reasonable assurance the applicant has shown the revised contents to be bounded by those of previously approved revisions. As a result, staff finds the applicant’s prior analyses on single packages and arrays of packages under normal conditions of transport and hypothetical accident conditions remain applicable with the proposed contents.

6.4 Evaluation Findings

The criticality safety method employed by the applicant complies with the requirements of 10 CFR 71.31(a)(2) and 10 CFR 71.35. The applicant previously showed that the evaluated system under both normal conditions of transport and hypothetical accident conditions were confirmed to have a maximum k_{eff} less than 0.95. Since staff finds the applicant showed reasonable assurance that the MTS S3G-3 contents are less reactive than existing, authorized contents, staff concludes that the Model M-140 containing a full load of MTS S3G-3 fuel modules under the assumptions utilized by the applicant continues to meet the criticality safety requirements in 10 CFR Part 71.

7.0 Materials Evaluation

The staff reviewed the application (Reference 1), which is an addendum to the safety analysis report (SAR), Revision 16 for to revise the CoC No. USA/9793/B(U)F-85 to ship the MTS S3G-3 spent fuel modules in the M-140 spent fuel shipping container, to verify that the material performance of the package meets the requirements of 10 CFR Part 71. Only the sections of the materials evaluation that changed from the previous SARs (Reference 2 and 3) will be discussed below.

7.1 Materials of Construction

The applicant submitted an SAR (Reference 1), as an addendum to the S3G-3 SAR (Reference 2), to demonstrate the material adequacy of the M-140 to transport the MTS specific S3G-3 spent fuel modules. No changes in the materials of construction were made to the M-140 packaging, which includes the S3G-3 internals. The MTS spent fuel modules are identical to the S3G-3 fuel modules in the previously approved package described in Reference 2, with the exception of minor geometrical differences in the upper fuel module structure (non-fueled hardware) of certain modules. No changes in the materials of construction were made to the MTS spent fuel modules. Per the above discussion, the staff finds that the applicant's description of the materials of construction to be acceptable.

7.2 Material Properties

The applicant did not make any changes to the mechanical and thermal properties of the materials used in the structural and thermal analysis. The staff notes that the values of package internal pressure and maximum decay heat values are bounded by the previously reviewed and accepted values. The staff also reviewed the new thermal HAC analysis and noted that resulting peak fuel temperatures were below the previously reviewed and accepted maximum values. Therefore, the staff finds the mechanical and thermal properties used in the applicant's structural and thermal analysis to be acceptable.

7.3 Spent Fuel

As stated earlier, the MTS spent fuel modules are identical to the S3G-3 fuel modules in the previously approved package described in Reference 2, with the exception of minor geometrical differences in the upper fuel module structure. The applicant provided a new method for determining fracture toughness of one the materials of construction of the fuel hardware, to account for a reduction of toughness due to thermal and radiation embrittlement. The applicant showed that this reduction in fracture toughness could lead to possible damaged structural members in the fuel hardware in an accident. The applicant demonstrated that this damage to structural members would not compromise the ability of the fuel assembly to perform its intended functions, nor would it compromise its ability to meet fuel-specific and package-related regulations. NRC staff notes that it did not evaluate the applicant's new method of determining fracture toughness of these structural members, since the assumed possible failure of these members did not affect the ability of the fuel to perform previously analyzed functions. As discussed previously, the values of maximum decay heat, as well as peak fuel temperatures resulting from HAC conditions, remained below the previously reviewed and accepted values, ensuring adequate margin is provided to the maximum fuel temperatures that could result in fuel cladding rupture. Therefore, the staff finds that the mechanical properties of the fuel modules are adequate to ensure that the SNF remains in the analyzed configuration under NCT and HAC.

7.4 Evaluation Findings

Based on a review of the statements and representations in the application (Addendum in Reference 1), the staff concludes that the materials used by the applicant are adequately described and evaluated for the transportation package design. The staff finds that the package complies with the requirements in 10 CFR Part 71 based on a review that considered the regulation, itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

7.5 References

1. WAPD-REO(C)-1395 – MTS Spent Fuel in the M-140 Safety Analysis Report for Packaging Addendum (U).

2. WAPD-REO(C)-1395 – S3G-3 Spent Fuel in the M-140 Safety Analysis Report for Packaging (U).

3. WAPD-REO(C)-1600 – Core Independent M-140 Safety Analysis Report for Packaging.

8.0 Operating Procedures

There were no changes to the operating procedures for the addition of the MTS S3G-3 contents.

9.0 Acceptance Tests and Maintenance Program

There were no changes to the acceptance tests or maintenance program due to the addition of the MTS S3G-3 contents.

CONDITIONS

The following changes have been made to the Certificate:

Condition 6c was revised to specify that the core age must be in accordance with Section 1.2.3.8 of the S3G-3 SAR with its Addendum.

Condition 14b was added to specify the minimum hold time prior to shipment.

Condition 18 was revised to reflect the new expiration date of the certificate.

The "REFERENCES" section was revised to include the date of the letters requesting renewal and the amendment and its supplement.

CONCLUSION

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

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