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

May 7, 2020

Mr. M. A. Kuprenas
NAVSEA 08Z
1240 Isaac Hull Ave SE Stop 8021
Washington Navy Yard, DC 20376-8021

SUBJECT: CERTIFICATE OF COMPLIANCE NO. 9788, REVISION NO. 20, FOR THE MODEL NO. S5G REACTOR COMPARTMENT DISPOSAL TRANSPORTATION PACKAGE

Dear Mr. Kuprenas:

By letter dated August 5, 2019, and as supplemented on January 30, 2020, the U.S. Department of Energy, Division of Naval Reactors (the applicant), submitted an application for revising Certificate of Compliance (CoC) Number (No.) 9788 to include the S5G reactor compartment as authorized content. Changes made to the enclosed certificate are indicated by vertical lines in the margin. The U.S Nuclear Regulatory Commission staff's safety evaluation report is also enclosed.

The approval constitutes authority to use the package for shipment of radioactive material and for the package to be shipped in accordance with the provisions of Title 49 of the *Code of Federal Regulations* 173.471.

If you have any questions regarding this certificate, please contact me or Norma García Santos of my staff at (301) 415-6999.

Sincerely,

John B. McKirgan

Digitally signed by John B. McKirgan
Date: 2020.05.07 07:47:33 -04'00'

John B. McKirgan, Chief
Storage and Transportation Licensing Branch
Division of Fuel Management
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-9788
EPID L-2019-LLA-0175

Enclosures:
1. Certificate of Compliance
   No. 9788, Revision No. 20
2. Safety Evaluation Report

cc w/encls 1&2:
R. Boyle, U.S. Department of Transportation
J. Shuler, U.S. Department of Energy,
c/o L. F. Gelder

SUBJECT: CERTIFICATE OF COMPLIANCE NO. 9788, REVISION NO. 20, FOR THE MODEL NO. S5G REACTOR COMPARTMENT DISPOSAL TRANSPORTATION PACKAGE

DATED: May 7, 2020

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ADAMS Package No.: ML20119A078 Letter & SER.: ML20119A079 CoC: ML20119A080

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SAFETY EVALUATION REPORT

Docket No. 71-9788
Model No. S5G Reactor Compartment
Certificate of Compliance No. 9788
Revision No. 20

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SAFETY EVALUATION REPORT
Docket No. 71-9788
Model No. S5G Reactor Compartment
Certificate of Compliance No. 9788
Revision No. 20

SUMMARY

By letter dated August 5, 2019, and as supplemented on January 30, 2020, the U.S. Department of Energy, Division of Naval Reactors (the applicant), requested the revision to Certificate of Compliance (CoC) Number (No.) 9788 [USA/9788/B(U)-96]. The applicant requested to revise CoC No. 9788 to include the S5G reactor compartment disposal package (RCDP).

The U.S. Nuclear Regulatory Commission (the staff) used the guidance in NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material," as well as associated regulatory guidance documents to perform the review of the proposed package changes. Based on the statements and representations in the application, as supplemented, and the conditions listed in this safety evaluation report (SER), the 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

1.1 Description of the Packaging and Package

The Model S5G, a defueled reactor compartment for one-time use is designed and fabricated to meet Type B(U) shipping package criteria in 10 CFR Part 71. The S5G Reactor Compartment package is approximately 46 feet (ft.) long and approximately cylindrical with a maximum diameter of approximately 33 ft. The RCDP consists of the following components, which has been separated from the remainder of the submarine hull and prepared for shipment by installing support fixtures for handling, jacking, and transport:

a. a defueled reactor compartment (including the cylindrical portion of the pressure hull),

b. fore/aft containment bulkheads,

c. reactor pressure vessel,

d. all reactor compartment systems,

e. contaminated valves, and

f. piping and components removed from fore/aft sections of the ship.

The maximum weight of the S5G package is 2,950,000 pounds (lb).

The containment boundary consists of both (forward and aft) containment bulkheads (with internal stiffeners) and cylindrical pressure hull.

1.2 Contents

The RCDP contents are composed of activated structural components associated with the reactor pressure vessel (largest source of activity) and CRUD (corrosion/wear products), including other reactor compartment components (e.g., steam generator) such as the following:

a. plant piping,

b. valves,

c. regenerative/non-regenerative heat exchangers,

d. ion exchanger resin, and

e. coolant purification system.

The reactor vessel is defueled, no fissile material (except trace) is present, and fluids were drained leaving only residual water in various locations of the plant (maximum of 1,200 gallons total). Reactor fuel, control rods, and control rod drive mechanisms (CRDM's) are all removed from the reactor core. All other reactor plant components and systems remain in their normal location. The CRDM penetrations, including all closure (pipe/component) penetrations are covered and seal welded with the reactor vessel closure head held in place by a closure assembly. The staff notes that the S5G RCDP has no impact limiters/energy absorption feature, no heat transfer regulators, no temporary shielding, and no criticality controls. In addition, maximum normal operating pressure is less than 100 psig; therefore, no pressure relief system or components are required. The package decay heat is less than 11 watts (W).

1.3 Drawings

The staff reviewed the figures and material tables in the application and verified that the applicant provided an adequate description of the S5G RCDP component functions, materials of construction, and fabrication (welding) specifications. The staff notes that the containment boundary high yield and high tensile strength steels conform to the appropriate military specifications. Therefore, the staff finds that the applicant provided sufficient information in the figures and application to describe the packaging materials.

2.0 STRUCTURAL AND MATERIALS EVALUATION

The staff reviewed the proposed changes to the RCDP certificate to verify that the applicant adequately evaluated the structural performance of the package for meeting the regulations of 10 CFR Part 71. The applicant is proposing to include the S5G, which is another variation of the RCDPs previously approved in this CoC.

2.1 Description of the Structure

The package consists of a portion of a submarine hull with containment bulkheads welded to each end that enclose a defueled reactor pressure vessel and certain components from other locations of the ship. As described in the Section 2.1 of the application, the staff notes that the S5G RCDP consist of major structural and safety significant reactor compartment components as follows:

a. ***Pressure Hull.*** A high yield strength steel cylindrical shell reinforced with T-shaped high yield strength steel frames (containment boundary).

b. ***Containment Bulkheads.*** Flat plate high tensile strength steel with interior stiffeners welded to the pressure hull fore/aft and together with the pressure hull form the S5G RCDP containment structure.

c. ***Shielded Passageway.*** High tensile/high yield strength steel construction, also contains lead and/or polyethylene shielding materials.

d. ***Reactor Pressure Vessel (RPV).*** Located on a steel support skirt attached to the Primary Shield Tank (PST). The PST, lead, and polyethylene shielding materials surround the RPV. The RPV is an alloy steel cylinder internally clad with a different alloy steel. The fuel unit and controls are removed. However, the following items remain:

    (1) closure head (fabricated/clad with similar RPV alloy steels and held in place by a closure assembly),

    (2) core basket upper flange (alloy steel),

    (3) bottom support w/stub tubes (alloy steel),

    (4) thermal shields (alloy steel),

    (5) flow distribution plate (alloy steel), and

    (6) thermal shields (alloy steel).

The containment boundary consists of the submarine hull and the forward and aft containment bulkheads. The containment boundary is designed to assure that loss or dispersal of the radioactive contents of the package and any increase in external radiation from internal components do not exceed the requirements of 10 CFR 71.51.

The staff reviewed the package structural design description and concludes that the contents of the application satisfy the requirements of 10 CFR 71.31(a)(1) and (a)(2) as well as 10 CFR 71.33. The staff also reviewed the structural codes and standards used in the package design and finds that these satisfy the requirements of 10 CFR 71.31(c).

Based on the information in the application, the staff finds that the applicant evaluated the package using a method of demonstration acceptable to the Commission, and therefore satisfies the requirements of 10 CFR 71.41(a).

2.2 General Requirements

2.2.1 Minimum Package Size

The smallest overall dimension of the package is greater than 4 inches (in.). Therefore, the requirement of 10 CFR 71.43(a) is satisfied.

2.2.2 Tamper Indicating Feature and Positive Closure

The S5G RCDP is a fully welded structure with no mechanical closures. Therefore, the requirement of tamper-indicating features of 10 CFR 71.43(b) does not apply and the requirement of positive closure of 10 CFR 71.43(c) is satisfied.

2.3 Lifting and Tie-Down Standards

2.3.1 Lifting Devices

There are no lifting devices that are a structural part of the package. Therefore, the requirements of 10 CFR 71.45(a) are not applicable.

2.3.2 Tie-Down Devices

There are no tie-down devices that are a structural part of the package. Therefore, the requirements of 10 CFR 71.45(b) are not applicable.

2.4 Evaluation of Material Properties

The tables in Section 2.2 of the application include specifications and temperature dependent physical and mechanical properties of the materials used in the S5G, including the following:

(1) yield strength,

(2) tensile strength,

(3) allowable strength,

(4) modulus of elasticity, and

(5) coefficient of thermal expansion.

In addition, Section 2.2 of the application also provides temperatures, density, and Poisson’s ratio values. The staff reviewed the packaging materials and their properties and found them to be acceptable. Sections 2.4.1 and 2.4.2 of this SER includes the staff’s evaluation of relevant material properties related to the S5G RCDP.

2.4.1 Base and Weld Metal Brittle Fracture

Section 2.1 of the application includes a discussion of fracture toughness of the base and weld metals used in the fabrication of the RCDP. The applicant stated that it used NUREG/CR-1815 (UCRL-53013), "Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers up to Four Inches Thick,” to evaluate brittle fracture. The applicant

also stated that the shield tank and support skirt are not part of the containment boundary and are fabricated from killed, fine grain steels, which have sufficient fracture toughness, to prevent fracture initiation at minor defects (per NUREG/CR-1815, Category III steels). Further, for other types of steel, fracture toughness testing must be performed. Therefore, explicit demonstration of fracture toughness by analysis was restricted to the RPV and all other S5G RCDP components are expected to lose containment during hypothetical accident conditions (HAC). The applicant stated fracture toughness of the RPV was evaluated at the lowest service temperature (LST) of 20 degrees Fahrenheit (ºF) and that analysis showed HAC loadings would not result in a through-wall fracture. In addition, the applicant stated that fracture toughness testing of the S5G RCPD is not necessary because the containment boundary consists of high yield/high strength steels, which are not fracture sensitive based on previous testing at the LST. The staff reviewed the applicant's test data and brittle fracture analysis and concludes that the applicant appropriately followed the guidance in NUREG/CR-1815 to demonstrate adequate fracture performance of the packaging materials.

2.4.2 Chemical, Galvanic, or Other Reactions

Section 2.2 of the application includes a discussion about reactions due to chemical, galvanic, or other reactions. The applicant stated that the RCDP is fabricated from ferritic steel, as is the reactor compartment structure and tanks. In addition, the reactor compartment piping systems and components are primarily fabricated from corrosion resistant alloy steels and no eutectic or galvanic combinations exist. Further, a seal welded containment boundary prevents in-leakage of water. The applicant stated that the residual liquid remaining within the RCDP is limited and isolated in plant vessels, system piping, and tanks and no measurable deterioration of these boundaries should take place during transportation. The applicant stated that a hydrogen/oxygen combination catalyst and absorbent was added to the RPV. The applicant stated the catalyst is not necessary to maintain hydrogen concentrations below 5% as hydrogen content is below 5% based on sampling of previous packages and a comparative analysis to those sampling results.

The staff finds that the components are fabricated from materials designated by appropriate commercial industry and/or military specifications. In addition, the materials are chosen, in part, because these are not susceptible to chemical or galvanic reactions and form a protective, passive, oxide layer. Further, the S5G RCDP steel external surfaces are painted to prevent corrosion. The staff finds no significant galvanic reactions are to be expected, based on the above discussion. In addition, the staff finds that the hydrogen control of residual RPV water provides reasonable assurance that chemical, galvanic, or other reactions will not occur during transportation of the S5G RCDP.

2.5 Codes and Standards

As described in the application, the staff notes that qualified personnel performed activities related to the design, fabrication, and examination of the S5G RCDP by using approved procedures aligned with the requirements of naval sea systems command (NAVSEA) codes, standards, specifications, criteria, and 10 CFR Part 71 requirements. The staff notes that the examinations must be performed by qualified individuals other than personnel that perform the welds, as identified in the NAVSEA, "Naval Nuclear Quality Control Manual." The staff finds the S5G RCDP materials specifications and standards to be acceptable because they adequately provide materials chemistry, mechanical properties, fabrication, and examination requirements.

2.6 Weld Design and Examination

The staff notes that the containment boundary welds of the S5G RCDP are both full and partial penetration welds. The staff notes that the application stated that all containment welds are, at a minimum, examined visually and, in addition, using magnetic particle examination on any welds performed on the containment boundary. The staff reviewed the weld design and finds it to be acceptable because welding and inspection will be performed in accordance to the NAVSEA technical publications, military standards and specifications.

2.7 Structural Evaluation under Normal Conditions of Transport

2.7.1 Heat

The materials of construction for the containment boundary have similar coefficients of thermal expansion. Therefore, differential thermal expansion is not a concern for this package.

The thermal load on the package is primarily due to solar heating. The applicant calculated the maximum internal normal operating pressure and it showed to be less than the minimum design pressure of the RCDP. Based on the applicant's analysis, the staff concludes that the S5G RCDP meets the requirements of 10 CFR 71.71(c)(1).

2.7.2 Cold

The materials of construction for the containment boundary have similar coefficients of thermal expansion. Therefore, differential thermal contraction is not a concern for this package.

The applicant calculated the minimum internal pressure as a result of the lowest normal operating temperature. The pressure difference caused by low temperatures is demonstrated to be significantly less than the pressure difference from the design external pressure. Based on this analysis, the S5G RCDP meets the requirements of 10 CFR 71.71(c)(2).

2.7.3 Reduced External Pressure

The applicant demonstrated that the design internal pressure of the RCDP is greater than the pressure difference caused by an external pressure reduction to 3.5 psia, which is required by 10 CFR 71.71(c)(3). The applicant determined that the reduced external pressure requirement is bounded by the design internal pressure of the RCDP. Based on this analysis, the staff concludes that the S5G RCDP meets the reduced external pressure requirement.

2.7.4 Increased External Pressure

The applicant evaluated the pressure hull at an external pressure significantly higher than the 20 psia required by 10 CFR 71.71(c)(4). Therefore, the applicant has shown the S5G RCDP meets this requirement.

2.7.5 Vibration Test

This package is transported via barge and low-speed land hauler for a one-time shipment. The applicant determined that the package is not susceptible to fatigue from a single shipment cycle and that the vibrations from transportation will not challenge the analyzed structural

capacity of the package. Based on applicant's assessment, the staff concludes that the S5G RCDP meets the requirements of 10 CFR 71.71(c)(5).

2.7.6 Water Spray

The S5G package is designed to withstand submergence in sea water up to 300 feet. The applicant considers that this design requirement is sufficient to bound the water spray requirement of 10 CFR 71.71(c)(6). Therefore, the staff concludes that the water spray requirement is satisfied.

2.7.7 Free Drop Test

The applicant analyzed the package in a one-foot, free drop as required by 10 CFR 71.71(c)(7). The applicant performed a series of conservative hand calculations to determine the bounding accelerations and deformations and the resulting effects on the containment structure and major internal components. The analysis resulted in no damage or penetration of the internal components or the containment boundary; therefore, the structural effectiveness of the package was not compromised. Based on the results of this analysis, the staff concludes that the free drop requirements are satisfied.

2.7.8 Corner Drop Test

The corner drop test does not apply since the gross weight of the package exceeds 100 kg in accordance with 10 CFR 71.71(c)(8).

2.7.9 Compression Test

The compression test does not apply since the gross weight of the package exceeds 5,000 kg, in accordance with 10 CFR 71.71(c)(9).

2.7.10 Penetration Test

The applicant assessed the bounding penetration scenario and calculated the penetration distance of the 1.25-in diameter, 13-lb steel cylinder dropped from 40 in. onto the package as required by 10 CFR 71.71(c)(10). This calculation showed the penetration has no effect on the containment boundary; therefore, the staff concludes that the S5G RCDP meets the penetration requirements.

2.7.11 Conclusion

The staff reviewed the structural performance of the packaging under the normal conditions of transport prescribed in 10 CFR 71.71. The staff concludes that there is no substantial reduction in the effectiveness of the packaging that would prevent it from satisfying the requirements of 10 CFR 71.51(a)(1) for a Type B package.

2.8 Structural Evaluation under Hypothetical Accident Conditions

2.8.1 Free Drop Test

The applicant analyzed the package for various, bounding drop orientations of a 30-ft free drop as required by 10 CFR 71.73(c)(1). The applicant performed a series of conservative hand

calculations to determine the bounding accelerations and deformations from each drop orientation and the resulting effects on the containment structure and major internal components. These analyses concluded that damage from a 30-ft drop would result in a breach of the containment boundary and the rupture of certain internal components, not including the stored reactor vessel.

The applicant determined that the damage and relative displacement of internal components for all free drop orientations was consistent with the assumptions in the thermal, containment, and shielding evaluations. The staff reviewed the applicant's assessments of structural damages and concludes that the damage assessments are representative of the structural condition of the package following the 30-ft drop, and there is no substantial reduction in the effectiveness of the packaging that would prevent it from satisfying the requirements of 10 CFR 71.51(a)(2). The effects of the damages on thermal, containment, and shielding evaluations are discussed in other sections of this SER. Section 4.3 of this SER addresses the containment evaluation of the S5G under HAC and notes the releasable activity is less than the regulatory limit of A_2 despite the assumed structural damage described above.

Based on the review of the aforementioned information, analysis methods, and calculated structural performance results, the staff has reasonable assurance to conclude that the requirements of 10 CFR 71.73(c)(1) are met for the free drop test.

2.8.2 Crush Test

This evaluation is not applicable due to the package mass exceeding 500 kg, per 10 CFR 71.73(c)(2).

2.8.3 Puncture Test

The applicant analyzed the S5G RCDP for various bounding drop orientations of a 40-in free drop onto the upper end of a 6-in, cylindrical, steel bar as required by 10 CFR 71.73(c)(3). The applicant performed a series of conservative hand calculations to determine the effects on the containment structure and major internal components. These calculations evaluated the energy generated by the puncture test, the resulting shear forces on the submarine pressure hull and then the stored RPV, and the capacities of those components. The applicant concludes that damage from the puncture test would result in a breach of the containment boundary and the rupture of certain internal components, but the stored RPV would not be ruptured following the test.

The applicant considered the reported damage from the puncture and free drop tests in the HAC evaluations of the thermal, containment, and shielding performance of the package. The staff agrees that these assumptions are representative of the structural condition of the package following the puncture and 30-ft drop tests, and there is no substantial reduction in the effectiveness of the packaging that would prevent it from satisfying the requirements of 10 CFR 71.51(a)(2). The thermal, containment, and shielding evaluations are discussed in Sections 3, 4, and 5 of this SER. Section 4.3 of this SER addresses the containment evaluation of the S5G under HAC and notes the releasable activity is less than the regulatory limit of A_2 despite the assumed structural damage.

Based on the review of the aforementioned information, the analysis methods, and calculated structural performance results, the staff has reasonable assurance to conclude that the requirements of 10 CFR 71.73(c)(3) are met for the puncture test.

2.8.4 Thermal Test

The thermal evaluation of the package considers the damaged condition of the structure resulting from the 30-ft drop and puncture tests. However, the fire temperature prescribed in the thermal test will not significantly alter the structural materials or the structural performance of the package as shown in the applicant's thermal evaluation and discussed further in the thermal evaluation section of this SER. Based on this analysis, the staff concludes that the package meets requirements of 10 CFR 71.73 (c)(4) for the thermal test. Section 3 of this SER includes the staff's thermal evaluation of the package.

2.8.5 Immersion Test

The immersion requirements of 10 CFR 71.73(c)(5) are not applicable to the S5G RCDP, because fissile material is not permitted for transport in this package. Also, the immersion requirements of 10 CFR 71.61 are not applicable to the S5G, because the total activity for the package is less than 10^5 A_2.

The S5G RCDP is designed to withstand submergence in sea water up to 300 ft. This design depth is significantly greater than the 50-ft immersion requirement for a separate, undamaged specimen per 10 CFR 71.73(c)(6). The staff concludes that the package satisfies the 50-ft immersion requirement and the 10 CFR 71.61 special requirements for Type B packages.

2.8.6 Conclusion

The staff has reviewed the structural performance of the packaging under the HAC prescribed in 10 CFR 71.73. The staff concludes that there is no substantial reduction in the effectiveness of the packaging that would prevent it from satisfying the requirements of 10 CFR 71.51(a)(2) for a Type B package. Despite the assumed damage, which includes a breach of the containment boundary, from the HAC assumed in the structural evaluations, the external release and dose rate of the S5G is shown to be under the regulatory limits of 10 CFR 71.51(a)(2) as discussed in Section 3 of this SER.

2.9 Evaluation Findings

Based on 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 package has adequate structural integrity to meet the requirements of 10 CFR Part 71. The staff also verified that the applicant appropriately followed the guidance in NUREG/CR-1815 to demonstrate adequate fracture performance of the packaging materials. The staff finds that the S5G RCDP materials meet the regulatory requirements of 10 CFR Part 71 for normal conditions of transport (NCT) and HAC and mitigating galvanic or chemical reactions, and it is constructed with materials and following processes in accordance with acceptable industry and/or military codes and standards.

3.0 THERMAL EVALUATION

3.1 Description of the Thermal Design

3.1.1 Design Features

Section 1.0 of this SER includes a description of the package. According to the application, the package is an all-welded single use container and is designed and built according to Navy specifications.

3.1.2 Content's Decay Heat

The applicant calculated a bounding decay heat of 9 W derived from shielding considerations, to which a design assurance factor was added, for a total calculated decay heat value of less than 11 W. However, the application's thermal chapter noted that the thermal analyses assumed a decay heat slightly below the total calculated decay heat value used for shielding considerations, but that using the smaller decay heat in thermal calculations would have no significant effect. The staff finds the decay heat used in the thermal analyses is acceptable because the difference between the two values is negligible.

3.1.3 Summary of Temperatures

The applicant noted in the thermal chapter that the maximum temperature of the accessible surface at NCT was 100ºF in the shade and a higher temperature when exposed to insolation. Both values are lower than the allowable accessible surface temperature for exclusive use transport. The thermal chapter also included package temperatures after the 30-minute hypothetical accident fire condition. However, as noted in the structural chapter of the application, these internal temperatures could increase if the package was previously punctured after a drop or puncture test. The impact of this scenario is discussed in the HAC thermal evaluation section provided below.

In the structural chapter, the applicant indicated that operational controls would be instituted such that the package would be shipped when temperatures are above the lowest service temperature of 20ºF.

3.1.4 Summary of Maximum Pressures

The thermal chapter noted that the maximum normal operating pressure (MNOP) was calculated to be less than the internal design pressure. The maximum pressure under HAC was calculated to be greater than the internal design pressure; as described in sections below, the analyses provided by the applicant considered the effect of a damaged containment boundary under HAC.

3.2 Material Properties and Component Specifications

The application included thermal conductivity, surface emissivity/absorptivity, and specific heat of the package materials.

3.3 Thermal Evaluation Under Normal Conditions of Transport

The applicant's thermal analysis was based on energy balances of the package surface. The thermal calculation for hot conditions assumed 100ºF ambient temperature and insolation. Likewise, the applicant assumed in its thermal analyses that the top of the package received a significant portion of the insolation, the effects from the side walls were negligible, and radiative heat transferrer occurred at the top of the package. It is noted that considering all package surface areas regarding insolation would increase temperature and pressure within the package. However, considering all package surface areas would still result in temperatures below the package metal's design temperature. Although any increase in the initial temperature and pressure during the beginning of the thermal HAC would result in an increase in the final pressure of the transient fire accident condition, this would not significantly change conclusions because the structural, containment, and shielding analyses were already based on a breach of the package after the fire.

Regarding cold temperature transport, according to the application's structural chapter, the main components of the package are acceptable for use at a low service temperature of 20°F. Therefore, the package would be shipped when ambient temperatures are above the low service temperature.

3.4 Thermal Evaluation Under Hypothetical Accident Conditions

The thermal analysis for the HAC was based on a lumped mass analytical approach and solving differential equations associated with the lumped masses. The initial conditions were based on the results from the NCT thermal analysis.

The structural and thermal chapters of the application indicated that the package temperatures due to the fire under HAC were below the melting point of the steel. According to the thermal chapter of the application, the resulting internal temperatures could result in an internal pressure above the design pressure, thereby, potentially resulting in a breach of the containment boundary. Likewise, the structural chapter of the application indicated that local penetrations after the drop and puncture accident tests could result in higher temperatures than assuming no penetrations. Therefore, the applicant noted in the structural chapter of the application that the shielding evaluation assumed the loss of shielding materials.

Thermal stresses were addressed in the structural chapter of the application. It was noted that any thermal stresses would not be significant compared to deformations caused by hypothetical accidents.

Although the structural and thermal chapters of the application indicated that the drop, puncture, and thermal HAC tests could potentially breach the containment boundary, the containment and shielding chapters of the application indicated that the package would still meet their respective regulatory requirements.

3.5 Evaluation Findings

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

4.0 CONTAINMENT EVALUATION

4.1 Description of the Containment System and Content

The containment analysis in the application is based on the S5G RDCP. This package is similar to the RDCP packages previously reviewed by the staff and certified for transport. According to the structural chapter of the application, the package is an all-welded single use container and is designed and built according to Navy specifications.

According to the application's containment chapter, the content includes activated metal, crud, ion exchange resin, and residual water; there are no powder aerosols. The non-releasable content includes activity that is alloyed into metal pieces as activated metal and a negligible activity from auxiliary systems. The non-fixed activity of the crud, ion exchange resin, and residual water was listed as a fraction of an A_2; only a negligible amount of that fraction could be released. The applicant noted that the releasable content is located in the internals of internal components and cannot come in contact with the containment boundary by becoming waterborne or airborne during NCT.

4.2 Containment Evaluation Under Normal Conditions of Transport

According to the containment evaluation chapter of the application, the maximum internal pressure in the package during NCT is below the design pressure. In addition, the structural and thermal chapters of the application indicate that the analyses show that the containment boundary would meet 10 CFR 71.51(a)(1) under NCT.

According to Chapter 8 of the application, the package undergoes an internal air pressure test prior to transport to ensure there is no gross leakage from the package; test ports are sealed and welded after the test. The test pressure is at least 50% higher than the maximum normal operating pressure, which demonstrates compliance with 10 CFR 71.85(b). The applicant noted in the application's containment chapter that the package undergoes a one-time shipment and, therefore, there are no periodic and maintenance leakage rate tests.

Confirmation of no gross leakage prior to transport, in combination with the fact the radioactive contents (i.e., activated metal and crud, resin, and residual water) are sealed within components and not in contact with the containment boundary, the applicant concluded there would be no release of radioactive contents under NCT, which demonstrates compliance with 10 CFR 71.51(a)(1).

4.3 Containment Evaluation Under Hypothetical Accident Conditions

As mentioned in the structural chapter of the application, there is potential for a breach of the containment boundary under drop, impact, and thermal HAC. However, as noted in the containment chapter of the application, the releasable activity is less than A_2 within the package. Therefore, the package meets the release limit of 10 CFR 71.51(a)(2). Sections 4.3.1 and 4.3.2 of this SER include additional information about the source term and releasable activity related to this package.

4.3.1 Source Term

The reactor is defueled, therefore, the radioactivity is limited to the following sources:

(1) the activated structural components;

(2) crud generated by reactor operations, which is present in the ion exchanger, and in the reactor system piping and components; and

(3) residual water that remains within the coolant system and in the reactor vessel.

Activated structural components are not considered releasable. Releasable radioactivity consists of crud and any residual liquids. For the containment analysis, the applicant conservatively assumed that all radioactivity present in the crud was cobalt-60 (^{60}Co). The quantity of krypton-85 (^{85}Kr) is negligible. Residual water that is left in the reactor vessel or internals will be absorbed by an inert absorbent, which is added to the package.

4.3.2 Releasable Activity

Structural evaluations showed that activated metals are not released during NCT and HAC. In addition, the applicant used previously used methods to show that the total amount of non-fixed activity was less than A_2. The applicant assumed the crud, resin, and water from the ion exchanger and associated piping systems and a portion of the remaining crud, associated with the reactor, was released after HAC. The applicant's analyses indicated that only a fraction of the non-fixed activity would be released, and, being less than A_2, would meet regulatory limits.

4.4 Evaluation Findings

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

5.0 SHIELDING EVALUATION

The applicant requested an amendment to the CoC USA/9788/B(U)-96 to include the S5G RCDP as authorized content. The purpose of this review is to verify that the S5G RCDP meets the external radiation requirements of 10 CFR Part 71 under NCT and HAC.

5.1 Description of the Shielding Design

5.1.1 Design Features

The S5G RCDP consists of a section of submarine hull containing the deactivated reactor compartment. All openings are sealed, and forward and aft containment bulkheads are welded onto the open ends of the hull. The contents consist of the defueled pressure vessel, reactor plant components normally located within the reactor compartment, and ion exchange resin. The control drive mechanisms are removed. Contaminated components may also be secured in the RCDP, and the applicant accounted for this radiation source in its analysis.

5.1.2 Summary Tables of Maximum Radiation Levels

Maximum radiation levels allowed under 10 CFR 71.47(b) for NCT are the following:

(1) 200 millirem per hour (mrem/hr) on the external surface of the package;

(2) 200 mrem/hr at the outer surface or vertical plane at the outer edge of an open, flat-bed style vehicle; and

(3) 10 mrem/hr at any point 2 m away from the outer, lateral surface of the vehicle.

Maximum radiation levels allowed under 10 CFR 71.51(a)(2) at 1 meter from the package surface (under HAC) are 1,000 mrem/hr. The applicant's analysis indicates that the package surface dose rates meet the first requirement of 10 CFR 71.47(b)(1), which also meets the dose rate limit in 10 CFR 71.47(b)(2). The applicant summarized calculated radiation levels in Tables 5.1-1 and 5.1-2 of the application for NCT and HAC, respectively, which are shown to be below the regulatory limits listed above.

5.2 Radiation Source

5.2.1 Gamma Source

The contents of this package consist of activated components, crud, and ion-exchange resin. The applicant presented the multigroup source strength in Tables 5.2-1 of the application. The irradiation history determines the magnitude of the source term. For activation sources, the applicant approximated a three-dimensional source distribution with a two-dimensional, discrete ordinates radiation transport code similar to the NEWT module in SCALE. The applicant modified the two-dimensional results with its axial distribution to estimate the three-dimensional flux distribution. The staff previously found two-dimensional discrete ordinates codes with axial segmentation reasonably accurate to determine flux history in this manner (ISG-8, "Burnup Credit in the Criticality Safety Analyses of PWR Spent Fuel in Transport and Storage Casks," Revision 3). Since there is only one S5G reactor compartment, the applicant used the actual power history from the cores used, shown in Section 5.2.1 of the application, to account for the neutron flux variation during core life. The applicant assumed that the worst-case flux profile existed across the lifetime of all cores. The staff finds this assumption acceptable because this will over-estimate component activation and increase calculated dose rates. The applicant assumed a maximum cobalt impurity content, rather than the actual cobalt content. The staff finds this assumption acceptable because this is expected to over-predict the source term, which will result in the calculated dose rates being conservative in comparison to the regulatory limits. For the crud sources, the applicant assumed an activity throughout the component surfaces that is more than twice as high as the largest source of crud measured. The staff finds this acceptable because assuming a larger source will conservatively over-predict external dose rates.

5.2.2 Neutron Source

There is no significant neutron source from the from the S5G reactor compartment disposal package.

5.3 Shielding Model

5.3.1 Configuration of Source and Shielding

The applicant's model explicitly models the components that are normally present in the reactor compartment during operation, as discussed in Section 5.3.1.1 of the application. The applicant assumed bulkheads and doors are either present or replaced with material to provide equivalent or greater shielding. The applicant did not include lead or polyethylene shielding that exists in the RCDP in its model. The staff finds this acceptable, since removing those components from the shielding model will over-predict external dose rates.

The applicant also applies an administrative factor under NCT that provides more margin to the regulatory dose limits. Under NCT, the applicant considered the contributions from activated components and crud, as shown in Table 5.3-1 of the application. The applicant determined the point of highest dose to be at the bottom of the package. Under HAC, the applicant considered three different types of drops. In all scenarios, the applicant assumed the larger activated components break free and shift in the direction of the drop to the maximum extent possible. The applicant assumes the ion exchange resin is released and relocates in the vicinity of a hypothetical puncture site. The staff finds this acceptable since it moves the source closer to the location being evaluated, which will increase the predicted dose rate.

To account for crushing as a result of a drop, the applicant removed components completely (e.g., hull material, or forward containment bulkhead). The staff finds this acceptable since the applicant removed material from the model that would shift, but still would be present to provide additional shielding. This assumption will increase the calculated dose rates.

5.3.2 Material Properties

The staff reviewed the material properties specified in the model and found them to be appropriate for the actual construction and contents of the package. A summary of mass and number densities used in the analysis is presented in Tables 5.3-3 and 5.3-4 of the application. The staff found that the applicant described and\or provided drawings in sufficient detail for staff to confirm the applicant's analysis for NCT and HAC.

5.4 Shielding Evaluation

5.4.1 Methods

The applicant calculated the external radiation form the source using SPAN-4, a three-dimensional, point-kernel code capable of modeling complex shield geometry, and iron dose build-up factors [WAPD-TM-809, "SPAN-4: A Point-Kernel Computer Program for Shielding," O.J. Wallace (Bettis Atomic Power Laboratory, Pittsburgh, Pennsylvania), 1969]. The staff finds this acceptable for the following reasons:

(1) there is only gamma-emitting material present;

(2) the code has the capability of modeling the applicant's geometry; and

(3) there is significant margin between the applicant's calculated dose rates and the regulatory limits.

5.4.2 Flux-to-Dose-Rate Conversion

The applicant used gamma flux-to-dose conversion factors that are contained in the SPAN-4 point-kernel code library and presented them in Table 5.4-1 of the application. The staff previously reviewed these factors and found them acceptable as SPAN-4 has a history of use in this manner [Agencywide Documents Access and Management System (ADAMS) Accession No. ML14346A656], and there is significant margin between the applicant's conservatively calculated dose rate and the regulatory limits.

5.4.3 External Radiation Levels

The applicant presented the dose rates under NCT and HAC in Tables 5.1-1 and 5.1-2 of the application, respectively. As discussed in prior sections, the staff finds that the applicant's analysis conservatively estimates the external dose rates. Considering there is significant margin between the peak dose rates and the limits in 10 CFR Part 71, even after the applicant applied an additional uncertainty multiplier, the staff finds, with reasonable assurance, that the dose rates will not exceed regulatory limits.

5.5 Evaluation Findings

Based on the staff's review of the methods, analyses, information presented in the application, prior staff review of the package, and for the reasons discussed above, the staff finds, with reasonable assurance, that the shielding requirements of 10 CFR Part 71 will be met with the proposed contents and packaging design.

6.0 CRITICALITY EVALUATION

The S5G RCDP is a non-fissile content, and therefore, does not require a criticality evaluation to comply with the requirements of 10 CFR Part 71.

7.0 PACKAGE OPERATION

In the application, Naval Reactors provided procedures for preparing the package for loading, loading the contents, preparing the package for transport, and unloading the package.

The staff reviewed the Operating Procedures in Chapter 7 of the application to verify that the package will be operated in a manner that is consistent with its design evaluation. On the basis of its evaluation, the staff concludes that the combination of the engineered safety features and the operating procedures provide adequate measures and reasonable assurance for safe operation of the proposed design basis fuel in accordance with 10 CFR Part 71.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

The applicant provided acceptance tests for the RCDP for visual inspection and measurements; weld examination, structural, and pressure tests; and leakage tests. The tests ensure that the package is fabricated in accordance with the drawings. The pressure tests are performed to satisfy the requirements of 10 CFR 71.85(b) (see Section 4.2 of this SER).

Since the package is for a one-time use, a maintenance program is not required.

The staff reviewed the acceptance tests and based on the statements and representations in the application, the staff concludes that the acceptance tests for the package meet the requirements of 10 CFR Part 71.

CONDITIONS

The certificate of compliance includes the following condition(s) of approval:

1) Condition No. 5.(a) was revised to add the Model No. S5G RCDP and its packaging description.

2) Condition No. 5.(b) was revised to add the S5G RCDP as authorized contents.

3) Condition No. 6 was revised with the following changes:

    a. Add a limit of up to 1,200 gallons of residual water in the S5G RCDP.

    b. Consolidate the limits of residual liquid allowed per RCDP in the new Table 1.

4) Condition No. 8 was revised as follows to clarify the temperature conditions in which the package can be shipped in relationship to the Lowest Service Temperature (LST):

    > "The Lowest Service Temperature (LST) must be determined for each package. The package shall not be shipped if the normal daily minimum temperature expected during the shipment of the package, as determined on the basis of weather forecasts, is less than the LST."

5) Condition No. 11 was revised to specify the conditions applicable to shipment of SSN 688 Class packages and add the following condition as requested by the applicant:

    "(b) submarines SSN 701 and SSN 711 reactor compartments are not authorized for shipment in the SSN 688 Class packages."

The staff revised the units "mr/hr" to "mrem/hr" to accurately reflect the dose rate units and made some editorial changes. The "References" section was revised to include the application provided as part of the review process.

CONCLUSION

Based on our review, the statements, and representations contained in the application and the conditions listed above, the NRC staff concludes that the Model No. S5G RCDP meets the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9788, Revision No. 20,
on May 7, 2020.