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

February 16, 2019

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. 19, FOR THE MODEL NOS. S5W REACTOR COMPARTMENT, SSN 688 CLASS AND NR-1 REACTOR COMPARTMENT TRANSPORTATION PACKAGE

Dear Mr. Kuprenas:

As requested by your application dated June 4, 2018, enclosed is Certificate of Compliance No. 9788, Revision No. 19, for the Model Nos. S5W Reactor Compartment, SSN 688 Class Reactor Compartment, and NR-1 Reactor Compartment transportation package. 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 Bernie White of my staff at (301) 415-6577.

Sincerely,

/RA/

John McKirgan, Chief
Spent Fuel Licensing Branch
Division of Spent Fuel Management
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-9788
EPID No. L-2018-LLA-0172

Enclosures:
1. Certificate of Compliance
   No. 9788, Rev. No. 19
2. Safety Evaluation Report

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

Subject: CERTIFICATE OF COMPLIANCE NO. 9788, REVISION NO. 19, FOR THE MODEL NOS. S5W REACTOR COMPARTMENT, SSN 688 CLASS AND NR-1 REACTOR COMPARTMENT TRANSPORTATION PACKAGE, DOCUMENT
DATED: February 16, 2019

Closes EPID No. L-2018-LLA-0172

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SAFETY EVALUATION REPORT
Docket No. 71-9788
Model Nos. S5W Reactor Compartment and
SSN 688 Class Reactor Compartment
Certificate of Compliance No. 9788
Revision No. 19

EVALUATION

By application dated June 4, 2018, the Department of Energy, Naval Reactors, requested amendment to Certificate of Compliance No. 9788. The amendment requested addition of the NR-1 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 interim staff guidance documents to perform the review of the proposed packaging changes. Based on the statements and representations in the application, as supplemented, and the conditions listed in the following chapters, 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

The Model NR-1, 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 NR-1 Reactor Compartment package is approximately 43 feet long and approximately cylindrical with a maximum diameter of approximately 12.5 feet. The NR-1 package has one containment bulkhead at the forward end of the package. The aft end of the package is the hemispherical head section of the hull. The new containment bulkhead is made of high strength steel and the hull is constructed of HY-80 steel. A 20-foot long box keel section remains attached to the bottom of the package. Additional plating of HS steel on the hull surrounds the pressure vessel region of the reactor compartment, and parts of the box keel. The maximum weight of the package is 406,500 pounds.

The NR-1 contents are composed of activated structural components associated with the NR-1 RCDP and CRUD (secured within the package), plant piping, and ion exchanger resin, which may be solidified in place. The NR-1 RCDP is defueled; therefore, no fissile material is present; fluids were drained and only a small quantity of residual liquid remains. The penetrations for the control rod drive mechanisms are plugged, and a canning cover and closure cover is welded over the RCDP closure head. All pipe and component penetrations are seal welded except for the removed neutron source penetration, which is closed utilizing a clamp ring. Only trace plutonium isotopes exist, but not exceeding 0.74 TBq (20 Curies). The package decay heat is less than 10 Watts.

2.0 STRUCTURAL AND MATERIALS EVALUATION

The applicant evaluated the NR-1 RCDP disposal package for compliance with the structural requirements of 10 CFR Part 71, under normal conditions of transport and hypothetical accident conditions. The package will not contain irradiated reactor fuel and is a one-time shipment

2.1 Description of the Structural Design

The NR-1 RCDP is comprised of a pressure hull, a reactor compartment bulkhead, and a welded containment bulkhead. The mid-section of the hull has additional steel plate welded circumferentially and there is a support structure attached to the keel region of the package.

The design criteria used to design the package include the following:

- Margin to yield uses allowable yield stress of the material,
- Component deformation without failure is acceptable, the deformation is quantified and applied to subsequent evaluations,
- Component deformation or partial failure is acceptable, the deformation and/or failure is quantified and applied to subsequent evaluations, and
- Component failure is acceptable, the failure is quantified and applied to subsequent evaluations.

2.2 Materials

The materials review was limited to the evaluation of the additional Model NR-1 RCDP contents. The applicant states that the pressure hull and hemispherical hull aft material are high yield steel. The forward containment bulkhead and conformal wrap material are of high-strength steel with toughness and low-temperature properties that are similar to that of the original hull plates that comprise the remainder of the package containment system. The forward bulkhead is welded to the reactor compartment structure with high strength, high-toughness filler metal that is similar to the chemical and physical properties of the base materials being joined. High-strength steel plates are welded to the hull to prevent punctures and act as radiation shielding.

The staff notes that the hull material is a low alloy steel with nickel, molybdenum and chromium, high yield strength, and low carbon content. It exhibits excellent notch toughness and good ductility. Since the structural materials of the submarine hull, closure bulkheads, and structural welds are ferritic steels, the potential for brittle fracture behavior under extremely cold temperatures was considered. The containment boundary high yield and high strength steels are previously tested and acceptable for use in a RCDP for lowest service temperature (LST) of 20 degrees F. In addition to the ability of the material to withstand extreme cold without being susceptible to brittle fracture, the operating procedures for the transportation of the RCDP conservatively preclude shipping if the weather forecast predicts minimum temperatures below the LST calculated for the package.

The applicant states that potential chemical, galvanic and other reactions of the RCDP were assessed for the transport period. The reactor piping systems and equipment are primarily constructed of corrosion resistant alloy steels. The pressurizer vessel, closure head, core basket, steam generator, main coolant piping, regenerative and non-regenerative heat exchangers, ion exchanger, associated pipes and valve material are fabricated from Alloy 600, a nickel-based alloy. The bolt ring and closure studs are high alloy steel. The applicant states

there are no eutectic or galvanic combinations at the maximum package temperature. The applicant states that a hydrogen/oxygen combination catalyst and absorbent was added to the pressurizer vessel to prevent radiolysis and ensure that the hydrogen gas concentration during shipment will be less than 5 percent by volume.

The staff finds that the components are fabricated from materials designated by appropriate commercial industry or military specifications. The materials are not susceptible to chemical or galvanic reactions. In addition, most components are fabricated from corrosion-resistant materials that form a protective, passive oxide layer, while the RCDP steel external surfaces are painted to prevent corrosion. The staff finds no significant material interactions or galvanic reactions are to be expected based on the above discussion. The staff finds the applicant performed extensive materials data characterization, including temperature dependence of physical properties, which provides reasonable assurance that the susceptibility of brittle fracture is low and the NR-1 RCDP is acceptable for transport. The NR-1 RCDP and packages constructed of similar materials have been previously approved and successfully transported.

The staff finds that the NR-1 RCDP materials meet the regulatory requirements of 10 CFR Part 71 for normal conditions of transport and hypothetical accident conditions, for mitigating galvanic or chemical reactions, and is constructed with materials and processes in accordance with acceptable industry/military codes and standards.

2.3 General Requirements for All Packages

2.3.1 Minimum Package Size

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

2.3.2 Tamper Indicating Feature

The NR-1 RCDP is a fully welded structure with no mechanical closures, therefore 10 CFR 71.43(b) is satisfied.

2.3.3 Positive Closure

The NR-1 RCDP is a fully welded structure with no mechanical closures, therefore 10 CFR 71.43(c) is satisfied.

2.4 Lifting and Tie-Down Standards for All Packages

2.4.1 Lifting Devices

There are no lifting devices that are a structural part of the package, therefore 10 CFR 71.45(a) is satisfied.

2.4.2 Tie Down Devices

The package is welded to a support structure and the stresses in the welds/base material are below allowables, therefore the package satisfies 10 CFR 71.45(b).

2.5 Normal Conditions of Transport

2.5.1 Heat

The only thermal load on the package is from the ambient temperature. In direct sunlight, the maximum internal pressure produced is approximately an order of magnitude less than the pressure used to evaluate the containment boundary, therefore there is no safety concern.

Differential thermal expansion is not a concern for this package because the materials of construction for the containment boundary have nearly identical coefficients of thermal expansion and the thermal gradients experienced during transport are less than those present during normal operating conditions.

2.5.2 Cold

Differential thermal contraction is not a concern for this package because the materials of construction for the containment boundary have nearly identical coefficients of thermal expansion.

2.5.3 Reduced External Pressure

The pressure hull was evaluated at a pressure significantly higher than experienced from this requirement, therefore there is no safety concern for reduced external pressure.

2.5.4 Increased External Pressure

The pressure hull was evaluated at a pressure significantly higher than experienced from this requirement, therefore there is no safety concern for increased external pressure.

2.5.5 Vibration

This package is transported via barge and low-speed land hauling; therefore, excessive vibrations are not credible, nor would this package be affected by wave motion present during barge transport. Further, given the mode of transport, fatigue of the materials of construction is not a safety concern for a one-time shipment.

2.5.6 Water Spray

Operating conditions for this package when in service is a maritime environment, therefore water spray has no effect on the package.

2.5.7 Free Drop

This package is evaluated for a free drop using the bottom, side drop orientation. The overall deformation from this drop orientation is negligible and the containment boundary remains intact; therefore, the package effectiveness is not compromised.

2.5.8 Corner Drop

This requirement does not apply to the NR-1 RCDP because it exceeds 220 lbs and it is not constructed of fiberboard or wood.

2.5.9 Compression

This requirement does not apply to the NR-1 RCDP because its weight exceeds 11,000 lbs.

2.5.10 Penetration

The energy produced by dropping a 13 lb cylinder through a distance of 40 inches onto the surface of the package is not sufficient to produce any significant damage to the containment boundary.

2.6 Hypothetical Accident Conditions

The NR-1 RCDP was evaluated for various hypothetical accident conditions including a 9-meter free drop with multiple orientations, hull puncture, reactor puncture, thermal effects and associated pressures, and water immersion.

2.6.1 Free Drop

Evaluations of the 30-foot (9 meter) free drop were performed for aft and forward end axial drops, side drops (top, lateral, bottom), as well as forward corner and aft oblique slapdown drops. These evaluations were done with explicit dynamic finite element analysis software that produces representative damage results with respect to gross damage assessment.

The reported damage and relative displacement of internal components for all free drop orientations was consistent with the assumptions used in the thermal, containment, and shielding evaluations and staff agrees that the methodology used is representative with respect to overall structural performance.

2.6.2 Crush

Due to the package mass being greater than 500 kg, a crush evaluation was not applicable.

2.6.3 Puncture

The hull and internal components were evaluated with finite element analysis methods for puncture due to impact on a 6-inch diameter puncture bar. The applicant noted that the hull evaluation showed a full and complete penetration while the reactor had sufficient stand-off distance from the penetration point to preclude puncture. The hull puncture was determined to be acceptable as it is the initial condition used for evaluating containment and shielding requirements.

2.6.4 Thermal

The thermal evaluation indicated that loss of lead shielding occurs as well as a loss of polyethylene shielding due to the fire. As with the puncture evaluation, these results are used as the initial conditions for both the shielding and containment evaluations.

2.6.5 Immersion – Fissile Material

Not applicable. This package does not contain fissile material.

2.6.6 Immersion – All Packages

With respect to water immersion of 50 ft for all packages, the design bases for both the pressure hull and defueling hull cuts bound the maximum pressure exerted by a 50-foot head of water.

2.6.7 Deep Water Immersion

With respect to deep water immersion equivalent to a pressure of 290 psi on the surface of the package, the calculated value for total activity is orders of magnitude below the regulatory limit of 10^5 A_2 therefore this test is not required, as specified in 10 CFR 71.61.

2.7 Conclusions

Based on the statements and representations in the application, the staff concluded that there is reasonable assurance that this package meets the structural requirements in 10 CFR Part 71 under normal conditions of transport and the hypothetical accident conditions, where applicable.

3.0 THERMAL EVALUATION

3.1 Description of Thermal Design

3.1.1 Design Features

The RDCP is sealed with welds and cannot be opened. The combined contents of the package produce less than 10 watts of decay heat. A model to analyze the thermal performance of the sealed NR-1 RDCP was developed by the applicant. Some support fixtures and features were omitted for the thermal analysis, which simplified the model and yielded conservative results, which maximized the temperature increase of the NR-1 RCDP during normal conditions of transport and the hypothetical accident condition fire. Additionally, the weights of some fixtures were omitted from the mass of the containment boundary, thus increasing the reported temperatures of the package.

The applicant performed the hypothetical accident conditions thermal evaluation following the 30-foot drop and puncture tests. The applicant stated, in Section 3.1.1 of the safety analysis report for Packaging (SARP), that as a bounding condition, the preceding tests will breach the containment boundary, but the applicant demonstrated that the breached package still satisfied regulatory requirements for containment and shielding, as discussed in SARP Chapters 4 and 5. Through the thermal analysis in SARP Chapter 3, the applicant demonstrated that even if the package were not to breach after the structural tests, the internal temperatures and pressures resulting from the hypothetical accident conditions fire condition would result in a breached package, which is consistent with the SARP bounding condition.

3.1.2 Content's Decay Heat

Per SARP Section 3.1.2, the applicant stated that as of July 1, 2014, the maximum decay heat was less than 10 watts. Staff agrees with the applicant that the decay heat will be further reduced at the time of shipment so the applicant's assumption of 10 watts throughout this evaluation is conservative.

3.1.3 Summary of Temperatures

Staff reviewed the summary of the package temperatures and confirmed that the package meets the 10 CFR 71.43 condition that no accessible surface would have a temperature exceeding 185°F for an exclusive use shipment in still air and shade with a 100°F ambient. Staff finds that the maximum component temperatures reached under normal conditions of transport do not surpass the component temperature limits.

3.1.4 Summary of Maximum Pressures

Staff reviewed the summary maximum pressures and notes that the hypothetical accident condition internal pressure would lead to a breach in the containment boundary. The staff finds that this assumption is consistent with the other SARP Chapters to show that the damaged package will meet regulatory requirements.

3.2 Material Properties and Component Specifications

Staff has verified that the appropriate thermal properties are specified, and that maximum allowable service temperatures, as discussed in SARP Chapter 2, are appropriate. In SARP Chapter 2 the applicant indicated that the main components of the containment boundary have been previously tested and shown to be acceptable for use in this package for the lowest service temperature of 20°F due to brittle fracture concerns, which does not meet the regulatory requirement of -40°F. Thus, the applicant stated in the operating procedures in SARP Chapter 7, that the package is operationally limited to allow transport only when the ambient temperature is greater than 20°F, which the staff finds acceptable.

3.3 Thermal Evaluation Under Normal Conditions of Transport

3.3.1 Heat and Cold

The thermal evaluation demonstrated that the analysis for normal conditions of transport does not result in a significant reduction in packaging effectiveness. As a conservatism in the analysis, the applicant assumed all areas of the package are curved, applying a higher temperature insolation rate than would actually be received since some of the package surfaces are flat, vertical surfaces.

The thermal analysis evaluated the response of the package as two lumped masses, which are thermally connected, the mathematical models that the applicant used are two nonlinear coupled differential equations. Staff has thoroughly reviewed the equations, calculations and assumptions used, and finds that the component temperatures and pressures do not exceed their allowable values, and that the maximum temperature of the accessible package surface is less than 185°F for exclusive use.

Per 10 CFR 71.71(c)(2), the applicant must evaluate the effect of an ambient temperature of -40°F in still air and the shade on the package. The staff finds that due to the negligible decay heat, the minimum temperature of the package and contents would be -40°F; however, as discussed in SER Section 3.2, and in SARP Chapter 2.1.2.1, the main components of the containment boundary have been tested and found acceptable for use at a low service temperature of 20°F, so the applicant stated the package will not be exposed to temperatures as low as -40°F.

3.4 Thermal Evaluation Under Hypothetical Accident Conditions

3.4.1 Initial Conditions

As discussed in the structural, containment, and shielding chapters of the SARP, the applicant established that as a bounding condition, the drop and puncture accidents may breach the containment boundary, but the applicant demonstrated that the package will still meet the regulatory requirements. In SARP Section 3.4, the applicant demonstrated that the fire temperature is below that of the melting point of the package steel components, so the heat of the fire would not further damage an already damaged package.

3.4.2 Fire Test Conditions

Despite the above discussion, the applicant performs a thermal analysis to assess the outcome of the fire accident for the condition that the package is <u>not</u> breached by the drop and puncture accidents. The applicant began the evaluation with initial steady-state temperature distribution consistent with the thermal evaluation under normal conditions of transport and an initial pressure consistent with the maximum normal operating pressure. Similar to the evaluation for normal conditions of transport, the applicant used lumped mass differential equations to evaluate hypothetical accident conditions. Staff has reviewed all calculations and assumptions and finds them appropriate.

3.4.3 Maximum Temperatures and Pressure

The applicant calculated the post-fire package pressure using the maximum boundary temperature, assuming the internal gas temperature may be the same as the boundary temperature. Based on this calculation, the applicant concedes that the package could breach. As discussed in the shielding chapter, the biggest radiological source is activated components and not releasable media, but with the media's contribution to dose being negligible compared to the rest of the source material. The staff finds that this conclusion is consistent with other SARP Chapters and that despite the breach, the package continues to meet the regulatory requirements.

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

4.1 Description of Containment System

The containment boundary of the RDCP is sealed closed with welds, and cannot be opened as there are no seals, closure bolts, penetrations, or closure devices. Per SARP Chapter 2.7.6, “Immersion,” the containment boundary will withstand an external pressure that exceeds the minimum 50 feet immersion capability specified in 10 CFR 71.73(c)(6).

4.2 Containment Under Normal Conditions of Transport

Per the results of the structural and thermal evaluations presented by the applicant in SARP Chapters 2 and 3, and as discussed in SER Chapters 2 and 3, the containment boundary will not breach under normal conditions of transport, and no radioactive material will be released from the package. Therefore, the staff finds that the package evaluation demonstrates compliance with 10 CFR 71.51(a)(1) under normal conditions of transport.

Although the package does not contain any fissile material, it does contain potentially releasable radioactive materials such as residual water, and crud. The applicant performed an evaluation in SARP Appendix 4.6 using the limiting chemical and physical forms of radioactive sources, including significant daughter products. The staff reviewed the evaluation and finds that all of the sources are shown to be retained under normal conditions of transport.

Internal Pressures and Structural Performance
The maximum internal pressure in the package during normal conditions of transport is below the maximum internal pressure the package can withstand, as demonstrated in SARP Section 2.6.3, thus, staff finds that containment will be maintained under normal conditions of transport.

Leakage Testing
Prior to shipping, the package is subjected, per SARP Chapter 8, to an internal air pressure test to verify the integrity, after which the tests ports are seal welded. The test pressure is at least 50 percent higher than the maximum normal operating pressure, which demonstrates compliance with 10 CFR 71.85(b).

4.3 Containment Under Hypothetical Accident Conditions

The applicant used the results of evaluations in SARP Chapters 2 and 3 to demonstrate regulatory compliance. Based on these evaluations, the containment boundary was breached under hypothetical accident conditions, and some activity was released; however, the staff finds that the applicant demonstrates in SARP Appendix 4.6 that the release is within the limits in 10 CF 71.51(a)(2).

The package does not contain fissile material. The applicant assumed 100% of the activity in residual water and ion-exchange resin is releasable in determining the releasable quantity of radionuclides for hypothetical accident conditions. One percent of the activity of the crud on the wetted surfaces of the package components is considered releasable. The applicant demonstrates, in SARP Chapter 2.7, that the activated structural components are retained within the package and are not available for release under hypothetical accident conditions.

Containment of Radioactive Material
As mentioned in SARP Chapter 2.7.8, a breach of the containment boundary occurs under hypothetical accident conditions, however, the applicant has demonstrated that any activated internals are retained within the package and, therefore, staff finds this acceptable.

After reviewing the amount of krypton-85 in the package at the time of shipment per SARP Table 4.6-1, the staff finds that the package meets 10 CFR 71.51(a)(2). The staff has reviewed the total releasable quantity of radioactive material and finds that no other radionuclides released from the package exceeds A_2 per week, and therefore the package complies with 10 CFR 71.51(a)(2).

4.4 Leakage Rate Tests for Type B Packages

Prior to shipping the package, as described in SARP Chapter 8.1.4, the applicant will conduct an internal air pressure test to verify the package integrity can withstand a test pressure at least 50% higher than the maximum normal operating pressure. The staff finds that this is an acceptable leakage rate test after confirming that the calculations in SARP Chapter 4 demonstrate that no radionuclides released from the package exceeds an A_2 quantity in the package, thus the package meets the containment requirements of 10 CFR Part 71. The staff finds it acceptable that there are no periodic or maintenance leakage tests for this package since this is a one-time shipment.

4.5 Evaluation Findings

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

5.0 SHIELDING EVALUATION

The applicant requested an amendment to the Certificate of Compliance USA/9788/B(U)-96 to include the NR-1 RCDP. The objective of this review is to verify that the NR-1 RCDP meets the external radiation requirements of 10 CFR Part 71 under NCT and HAC.

5.1 Description of Shielding Design

5.1.1 Design Features

The NR-1 RCDP consists of a section of the NR-1 hull with a steel, containment bulkhead added to the forward end of the package. A steel conformal wrap is added that extends over part of the box keel. Additional steel plating is attached in places, which the applicant details in Section 5.1.1 of the SARP. The contents consist of the defueled pressure vessel and reactor plant systems and decking normally located within the reactor compartment. Contaminated components may also be secured in the RCDP, and the applicant included those components 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: 200 mrem/hr on the external surface of the package; 200 mrem/hr at the outer surface or vertical plane at the outer edge of an open, flat-bed style vehicle; and 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 a distance of 1 m from the package surface under HAC are 1000 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 in the SARP 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 and crud; however, crud is only a significant contributor in locations of the package where activation contribution is negligible. The applicant presented the multi-group source strength in Tables 5.2-2 and 5.2-3 of the SARP for activation and crud, respectively. 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 an axial distribution to estimate the three-dimensional flux distribution. Staff previously found two-dimensional discrete ordinance codes with axial segmentation reasonably accurate to determine flux history in this manner (Interim Staff Guidance No. 8 (ISG), Rev. No. 3, “Burnup Credit in the Criticality Safety Analyses of PWR Spent Fuel in Transport and Storage Casks”). The applicant used actual core power history, shown in Table 5.2-1 of the SARP, to account for the neutron flux variation from axial power shifting during core life. The applicant performed measurements of the activated components to determine the calculated to measured (C/M) ratios. The applicant assumed a maximum cobalt content, rather than the actual cobalt content. Staff finds this acceptable as this is expected to over-predict the source term. Since the NR-1 is a unique vessel, the applicant measured the activated components and found the minimum C/M ratio to be 2.2. The applicant applied this minimum correction only to the components, specified in SARP Section 5.2.1.1.1, which are the primary contributors to the dose rate, even though the C/M ratio for those components was much higher. Staff finds this acceptable as the C/M ratios are actually higher for those components to which the applicant applied the correction, and the applicant did not reduce the predicted activation for any other components. The applicant also applied administrative factors to the activation calculations that conservatively increase the calculated source term. Staff finds this acceptable as the conservative source term will result in the calculated dose rates being conservative in comparison to the regulatory limits. For the crud sources, the applicant measured radiation in the reactor compartment after shutdown and included those sources in Table 5.2-3 of the SARP. Staff finds this acceptable as it is an accurate measurement of the actual source.

5.2.2 Neutron Source

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

5.3 Shielding Model

5.3.1 Configuration of Source and Shielding

The applicants’ model ignores the presence of many structural components, as discussed in SARP Section 5.3.1.1. Staff finds this acceptable since not crediting the presence of these components in the model will under-estimate shielding and over-predict dose rates. Under NCT, the applicant only considered activated components as the contribution from crud is negligible, as shown in Tables 5.2-2 and 5.2-3 of the SARP. The applicant models the activated components shifted downward to the fullest possible extent as a result of a 1-foot drop. Staff finds this acceptable since it moves the source material as close as can be reasonably expected to the point of highest dose rate toward the bottom of the hull where it meets the box keel.

Under HAC, the applicants' model assumed all lead, polyethylene and graphite to be lost. In addition, the applicant's model ignored self-shielding from many of the radioactive source components within the RDCP under HAC, as discussed in detail in SARP Section 5.3.1.2. The staff finds that this is conservative since it removes material from the analysis that might otherwise be present to provide additional shielding. Depending on the orientation of the assumed drop, the applicant modeled the source material shifted to the fullest extent possible, accounting for deformation and crushing, within the cavity of any confining components. The applicant accounted for streaming pathways by modeling source material in line with nozzles and penetrations, which is an unlikely configuration for the accident condition. Staff finds this acceptable since the applicant conservatively models source material in line with points of minimized shielding and potential streaming pathways. For the most limiting accident scenario, the applicant assumes the maximum deformation occurs over the entirety of the drop face. The staff finds this is conservative as only a portion of the crushed component would deform to the maximum extent. In all drop scenarios, the applicant conservatively modeled any puncture as near as possible to and aligned toward the most significant source material. Staff finds this acceptable since it minimizes shielding for significant radiation sources.

5.3.2 Material Properties

Staff reviewed the material properties specified in the model and found them to be appropriate for the actual construction and contents of the package. A summary of mass and number densities used in the analysis is presented in Table 5.3-3 of the SARP. While the applicant did not necessarily consider minimum dimensions due to tolerances, they did omit a large number of steel structural components, and in some cases the applicant modeled steel material as polyethylene. Staff finds the contribution of these omitted components, some of which are substantial, is acceptably conservative in lieu of slightly reduced dimensions due to tolerances.

The staff found the applicant described and/or provided drawings of sufficient detail for NRC staff to confirm the applicant's analysis for both NCT and HAC.

5.4 Shielding Evaluation

5.4.1 Methods

The applicant calculated the external radiation from 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 because: there is only gamma-emitting source material present; the code is capable of modeling the applicant's geometry; and there is significant margin between the applicant's calculated dose rates and the regulatory limits.

5.4.2 Input and Output Data

Due to the sensitive nature of the software, the staff did not perform a confirmatory analysis using the applicant's input data. However, the staff found sufficient source and shield geometry information in the SARP to assess the applicant's methodology.

5.4.3 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. Staff previously reviewed these factors and found them acceptable as SPAN-4 has a history of use in this manner (ADAMS Accession No. ML14346A656) and there is significant margin between the applicant's conservatively calculated dose rate and the regulatory limits.

5.4.4 External Radiation Levels

The applicant presented the dose rates under NCT and HAC in Tables 5.1-1 and 5.1-2 of the SARP, respectively. As discussed in prior sections, staff finds 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, staff finds reasonable assurance that the dose rates will not exceed regulatory limits.

5.5 Conclusion

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

6.0 CRITICALITY EVALUATION

The NR-1 RCDP is non-fissile, 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 that are specific to the NR-1 RCDP 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 NR-1 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 is performed to satisfy the requirements of 10 CFR 71.85(b), since the maximum normal operating pressure is greater than 5 psig. The test is a pressure drop test.

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

NRC 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

Condition 5.(a) was modified to add the Model No. NR-1 Reactor Compartment Disposal Package and its package description.

Condition 5.(b) was revised to add the NR-1 RCDP as authorized contents.

Condition 6 was revised to limit the residual water to less than 90 gallons for the NR-1 RCDP.

Condition 15 was modified to state that the package must be operated, maintained, and acceptance tested in accordance with the application, as supplemented.

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. NR-1 RCDP meets the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9788, Revision No. 19.