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

July 25, 2016

Mr. Barry K. Miles
Naval Reactors
Department of Energy
Washington, DC 20585

SUBJECT: CERTIFICATE OF COMPLIANCE NO. 9186, REVISION NO. 17, FOR THE MODEL S-6213 POWER UNIT SHIPPING CONTAINER

Dear Mr. Miles:

As requested by your letter dated June 22, 2015, as supplemented on April 28, 2016, enclosed is Certificate of Compliance No. 9186, Revision No. 17, for the Model Nos. Model 1, S-6213 Power Unit Shipping Container and Model 2, S-6213 Power Unit Shipping Container. Changes to the enclosed certificate are indicated by vertical lines in the margin. The 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 49 CFR 173.471.

If you have any questions regarding this certificate, please contact me or Bernard 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. 71-9186
CAC No. L25034

Enclosures: 1. Certificate of Compliance
2. Safety Evaluation Report

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

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ADAMS Package No.: ML16208A205 Letter & SER: ML16208A226

CoC: ML16208A227 (This closes CAC No. L25034.)

OFC:	DSFM	DSFM	DSFM	DSFM	DSFM
NAME:	BWhite	SFigueroa via email	JChang via email	JBorowsky via email	YKim via email
DATE:	7/5/16	7/14/16	7/6/16	7/6/16	7/12/16
OFC:	DSFM	DSFM	DSFM	DSFM	DSFM
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SAFETY EVALUATION REPORT
Docket No. 71-9186
Model Nos. Model 1, S-6213 Power Unit Shipping Container and
Model 2, S-6213 Power Unit Shipping Container
Certificate of Compliance No. 9186
Revision No. 17

SUMMARY

By application dated June 22, 2015, as supplemented on April 28, 2016, U.S. Department of Energy (DOE), Division of Naval Reactors (Naval Reactors or the applicant) requested the U.S. Nuclear Regulatory Commission (NRC) amend the Certificate of Compliance No. 9186, for the Model Nos. Model 1, S-6213 Power Unit Shipping Container (PUSC) and Model 2, S-6213 Power Unit Shipping Container transport packages. Naval reactors requested the addition of an unirradiated S9G power unit containing the Virginia Forward Fit (VAFF) core as authorized contents.

NRC staff reviewed the applicant's request and found that the package meets the requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 71.

1.0 GENERAL INFORMATION REVIEW

The NRC staff reviewed Naval Reactors description of the S9G Power Unit containing the VAFF core. The staff concludes that the applicant has provided an adequate description of the package which was used as the basis for the evaluation of the packages against the requirements in 10 CFR Part 71 for each technical discipline.

2.0 STRUCTURAL REVIEW

The objective of the structural evaluation is to verify that the structural and materials performance of the package is adequately demonstrated to meet the requirements of 10 CFR Part 71. The staff limited the scope of the structural review to the areas of the safety analysis report that are affected by the new contents.

2.1 Description of Structural Design

2.1.1 Discussion

The S-6213 Models 1 and 2 PUSCs that are being used to ship power units containing the cores. The structural analyses and designs of these two S-6213 PUSCs with the power units (S8G and S6W) containing the cores had been reviewed by the staff, and the staff previously issued a safety evaluation report.

The applicant has submitted a revised safety analysis report (SAR) for the S-6213 PUSCs that will be used to ship a new power unit (S9G) containing the cores. The applicant indicated that the structural analyses for the S-6213 PUSCs with the S9G power unit containing the cores are similar to the analyses for the S-6213 PUSCs with the S6W power unit containing the cores. The differences in these two SAR analyses (S9G vs. S6W) are attributed mainly to design differences between the S9G and S6W power units, such as the power unit weights, materials and dimensions. Therefore, the applicant submitted only revised pages of the SAR that are affected by the design changes, and the staff reviewed the revised SAR accordingly.

2.1.2 Design Criteria

The applicant used the design criteria with the load combinations and load factors for evaluating design adequacy of the S-6213 PUSCs with the S9G power unit, which are same as the design criteria previously used for evaluating designs and analyses of the S-6213 PUSCs with the S8G and S6W power units. The applicant used combinations of closed-form solutions, hand calculations, and finite element analyses to evaluate the S-6213 package. Linear elastic analyses were performed for normal conditions of transport and bilinear elastic-plastic analyses were performed for hypothetical accident conditions.

2.2 Weights and Centers of Gravity

The applicant calculated the weights and centers of gravity for the S-6213 PUSCs with the S9G power unit. The values of the nominal weights and the locations of the centers of gravity for various power unit components are provided in Figure 2.2-1 and Table 2.2-1 of the SAR.

2.6 Normal Conditions of Transport

2.6.1 Heat

The applicant performed analyses to calculate the stresses of the components and joints of the S-6213 PUSC with the S9G power unit containing the VAFF core under hot (+120°F) conditions. The results of all stress calculations were compared with the allowable stresses. Based on the review of the comparisons between the calculated and the allowable stresses provided in the SAR, the staff finds that the stress intensity values at critical components and joints under the hot conditions are within the allowable limits of the materials, therefore, the calculated stresses are acceptable.

2.6.2 Cold

The applicant performed analyses to calculate the stresses of the components and joints of the S-6213 PUSC with the S9G power unit under cold (-40°F) conditions. The results of all stress calculations were compared with the allowable stresses. Based on the review of the results provided in the SAR, the staff finds that the stress intensity values at critical components and joints under the cold conditions are within the allowable limits of the materials, therefore, the calculated stresses are acceptable.

2.6.3 Reduced External Pressure

The evaluated package design pressure of 36 psig bounds the effects of reduced external pressure (3.5 psia).

2.6.4 Increased External Pressure

The evaluated package design pressure of 36 psig bounds the effects of increased external pressure (20 psia).

2.6.5 Vibration

The applicant performed dynamic analyses using the ANSYS computer program to evaluate the effects of vibration for individual parts, assemblies, and fastened connections of the S-6213 package and its contents. The results of the analyses showed that the S-6213 PUSC S9G containing a VAFF core, internals and cargo components are almost not affected by resonant amplification. The applicant compared the resulting stresses with the allowable stresses, and demonstrated that the calculated stresses are lower than the allowable stresses and meet the design criteria.

The staff reviewed the analyses and verified the stress calculations. Based on the review, the staff determined that the evaluation to analyze the effects of vibration on the package is acceptable.

2.6.6 Water Spray

The S-6213 PUSCs are designed to withstand positive and negative pressures. In addition, no external surfaces are absorbent or reactive to water. Due to the construction materials of the S 6213 PUSC, the staff determined that water spray is not a significant challenge to the structural design of this package.

2.6.7 Free Drop

The applicant provided detailed evaluations of the S9G power unit for the g-load due to a 30-foot side drop accident condition as presented in Appendix 2.10.2 of the SAR. The evaluations showed that the power unit remained intact with the fuel and the control rod configuration unchanged from the 30-foot side drop. Because a subcritical arrangement was maintained after the hypothetical accident condition scenarios and there was no significant rearrangement of the spent fuel, the applicant concluded that (i) a subcritical arrangement will be maintained for the 1-ft drop, and (ii) the geometric form of the package contents would not be substantially altered. The staff determines that the applicant's evaluation conclusions are acceptable based on the reasons delineated above.

The staff reviewed the structural performance of the S-6213 PUSC package under the normal conditions of transport conditions, and concludes that the package has adequate structural integrity to satisfy the requirements of 10 CFR Part 71.71.

2.7 Hypothetical Accident Conditions

The applicant performed the structural analyses for S-6213 PUSC with S9G power unit containing a VAFF core for hypothetical accident conditions. The results of the analyses are provided in Appendices 2.10.1 through 2.10.4 of the SAR.

2.7.1 Free Drop

The applicant performed three free drop analyses for the S-6213 PUSC and S9G power unit: (i) 30-foot top and bottom drop, (ii) 30-foot side drop, and (iii) 30-foot corner and oblique drop. The applicant used combinations of hand calculations and finite element computer programs to evaluate the S-6213 PUSC and the S9G power unit containing a VAFF core. A summary of the results of the analyses are provided in the SAR. The staff reviewed the results of the analyses,

and found that the applicant demonstrated: (i) no loss of primary containment, (ii) no contact of the closure head and the containment cover, (iii) no contact between top impact limiter and the power unit, (iv) no top impact limiter breach, (v) no failure of attachment components, and (vi) elastic behavior of the packaging cover and fasteners.

2.7.4 Pin Puncture

The applicant evaluated the S-6213 PUSC and S9G power unit containing a VAFF core for a 40-inch puncture drop, and provided the analysis results in Table 2.10.4-1 of the SAR. The results show that the S-6213 PUSC upper barrel, upper cover, and barrel impact limiter regions were not punctured during the hypothetical puncture accident. The lower barrel region of the S-6213 PUSC was punctured and the pin did impact, but not penetrated into the core basket. There was no significant damage to the contents subsequent to penetration of the container wall. Based on the results, the staff determined that the applicant demonstrated that the package function is not impaired due to the puncture impact.

2.7.5 Thermal

Summary of Pressures and Temperatures: The pressures and temperatures associated with the 1475°F fire hypothetical accident conditions are summarized in Section 2.7.5.1 of the SAR.

Differential Thermal Expansion: The maximum stresses, which can be expected due to differential thermal expansion caused by the 1475°F fire, were calculated for critical package joints.

Stress Calculations: The applicant used a combination of hand calculations and closed form solutions to determine stresses due to thermal expansion for the critical package units. The maximum stresses were calculated for critical package joints as presented in Section 2.7.5.3 of the SAR.

Comparison with Allowable Stresses: The applicant compared the results of the thermal stress analyses with the allowable stresses. The applicant found that the elongation in the studs, due to the worst case temperature differential between the main flange studs and container flanges, was well below the maximum uniform elongation capability of the stud material. Based on the findings, the applicant concluded that all critical package joints, including the main flange joints and all power unit joints which affect control rod position, remain intact during the hypothetical 1475°F fire accident. Based on the review of the evaluation, the staff found that the conclusion is acceptable that the induced stresses do not affect the overall containment performance of the S-6213 PUSC and the S9G power unit.

2.7.6 Immersion – Fissile Materials

The criticality analyses of Chapter 6 of the SAR, as discussed below, shows that the VAFF core remains subcritical.

The staff reviewed the structural performance of the S-6213 PUSC package under the hypothetical accident conditions, and concludes that the package has adequate structural integrity to satisfy the subcriticality, containment, shielding, and temperature requirements of 10 CFR Part 71.73.

2.8 Evaluation Findings

Based on review of the statements and presentations 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 in 10 CFR Part 71.

3.0 THERMAL REVIEW

The objective of this review is to verify that the S-6213 PUSC, loaded with the VAFF fresh fuel, satisfies the thermal requirements of 10 CFR Part 71 under normal conditions of transport and hypothetical accident conditions.

3.1 Thermal Design and Decay Heat

The S-6213 PUSC is a closed vessel equipped with two pressure relief valves discharging to the ambient and is used to ship a new, unirradiated S9G power unit containing the VAFF fresh fuel. The power unit is shipped dry in the S-6213 PUSC and pressurized with the dry nitrogen gas. The S9G VAFF fresh fuel has essentially no decay heat. The only heat sources are external to the container.

The staff has reviewed the package description and thermal design/mechanism relative to the changes associated this request and concludes that the application is acceptable per thermal requirements of 10 CFR Part 71.

3.2 Material Properties and Component Specifications

The applicant summarized the packaging components and the material properties in Section 3.2 of the SAR. The staff reviewed the description of the packaging components and material properties and confirms that there is no change in packaging components and their thermal properties for S-6213 PUSC when loaded with proposed contents.

3.3 Thermal Evaluation under Normal Conditions of Transport

The applicant described the thermal model in Section 3.4.6 of the SAR with a constant peak solar heat and absorptivity/emissivity of 0.9. The thermal model and thermal evaluations for the both the S-6213 Model 1 and Model 2 PUSC packages were provided in the previous SAR and were approved by the NRC. The applicant concluded in Section 3.4 of the SAR that (1) the maximum temperature of each component, including O-ring, will not exceed its corresponding limit, (2) the container surface temperature remains below 185°F in the shade, as required by 10 CFR 71.43 for an exclusive use shipment, (3) the minimum temperatures will be equal to the minimum ambient temperature specified as -40°F, with no adverse effect to the package components, and (4) the maximum internal pressure under normal conditions of transport is below the design limit.

The staff reviewed the thermal model and evaluation in Section 3 of the SARP and confirmed that (a) the thermal evaluation is acceptable with maximum component temperatures, maximum internal pressure, and maximum thermal stress below the corresponding limits under the hot conditions for normal conditions of transport and (b) there is no adverse operational effect under the cold conditions of -40° in still and shade for normal conditions of transport.

Based on conditions (a) and (b), the staff agrees with the applicant's conclusions in items (1) through (4), above, and confirmed that shipment of the S9G Power Unit Core containing VAFF fresh fuel under normal conditions of transport meets the thermal requirements in 10 CFR 71.71.

3.4 Thermal Evaluation under Hypothetical Accident Conditions

The applicant stated in Section 3.5 of the SAR that the thermal model used for the evaluation for hypothetical accident conditions is the same as that used in previous applications which was reviewed and resulted in a certificate of compliance from the NRC. In the thermal model, the heat absorbed by the S-6213 PUSC is calculated based on convection and radiation between 1475°F fire source and the package.

The applicant re-performed thermal analyses using an exchange factor of 0.9 per NRC's request for additional information, dated February 5, 2016, (ADAMS Accession No. ML16036A317), and calculated the maximum average temperatures of the shell and PUSC, based on an initial temperature of 100°F prior to the fire. The applicant noted in Section 3.5.1.1 of the SAR that, due to the central location of the fuel elements and the presence of several insulating air gaps, the fuel elements remain cooler than the maximum average S-6213 PUSC packaging temperature during the fire transient.

The staff reviewed the applicant's calculated temperatures based on an exchange factor of 0.9 and accepted the HAC thermal analysis because both the shell and PUSC temperatures are below the limits with the significant margins. The staff also accepts that the fuel elements will remain even cooler than the maximum average S-6213 PUSC temperature during the fire transient because of presence of insulating air gaps within S-6213 PUSC.

The applicant stated in its response to the NRC's request for additional information that the internal S-6213 PUSC pressure was re-calculated (based on the increased shell temperature under an exchange factor of 0.9) and is over the container joint capability. Therefore in the event of relief valve failure, the O-rings would become unseated and allow venting to occur.

Based on the component temperatures calculated using an exchange factor of 0.9 for radiation heat transfer, the staff determined that the applicant's thermal evaluation for hypothetical accident conditions is acceptable because the thermal model is appropriate and the package component temperatures are below their respective limits. The staff confirmed that shipment of the S9G power unit containing the VAFF core meets the thermal requirements in 10 CFR 71.73.

3.5 Evaluation Findings

Based on review of statements and representations for the thermal evaluations in this proposed amendment, the staff determined that (a) the thermal design features of the S-6213 PUSC remain unchanged and (b) the thermal analyses are discussed in sufficient detail for verification of normal conditions of transport and hypothetical accident conditions. The staff concludes that the S-6213 package when loaded with an S9G Power Unit containing the VAFF fresh fuel meets the thermal requirements of in 10 CFR Part 71.

4.0 CONTAINMENT REVIEW

The objective of the review was to verify that the containment boundary of the S-6213 PUSC, which will be used to transport the S9G power units containing the VAFF core, was adequately described and evaluated under normal conditions of transport and hypothetical accident conditions to meet regulations, as required by 10 CFR Part 71. The application included the addition of a new, unirradiated fuel as content; there were no changes to the containment boundary design. Regulations applicable to the containment review include 10 CFR 71.31, 10 CFR 71.33, 10 CFR 71.35, 10 CFR 71.43, and 10 CFR 71.51.

According to Chapter 4 of the SAR, the containment boundary consists of cladding surrounding the fuel. In response to NRC's request for additional information, question 4-1, the applicant stated that fabrication and inspection processes are highly controlled. The SAR states that visual, ultrasonic, and radiographic tests are performed to ensure there are no cracks associated with the containment boundary. In addition, operational monitoring of reactor coolant and post-irradiation inspections of similar fuel designs indicate the containment boundary has no credible leakage. The containment boundary is enclosed within the S-6213 container, which includes bolted-closed steel sections and impact limiters. According to Chapter 8 of the SAR, the S-6213 container is pressurized with an inert gas and that a pressure drop leakage test is performed.

4.1 Normal Conditions of Transport

Chapter 4 of the SAR indicated that there are no breaches of the containment boundary as a result of the normal conditions of transport tests defined in 10 CFR Part 71.71. Although the containment boundary is not leak tested, the applicant indicated that stresses in the fuel cladding remain below the cladding's yield strength. The applicant stated that the release fraction from the containment boundary is zero due to the low stress experienced during normal conditions of transport and the containment's unique design and fabrication.

4.2 Hypothetical Accident Conditions

Chapter 4 of the SAR indicated that there are no breaches of the containment boundary as a result of the tests defined in 10 CFR Part 71.73. For example, stresses in the cladding are below yield for the 30-foot side drop test and fuel cladding is below its allowable temperature during the fire test. Although the containment boundary is not leak tested, the applicant indicated that stresses in the fuel cladding remain below the cladding's yield strength. The applicant stated that the release fraction from the containment boundary is zero due to the low stress experienced during hypothetical accident conditions and the containment's unique design and fabrication.

4.3 Conclusions

Based on review of the statements and representations in the application, the staff concludes that the containment design of the S-6213 unirradiated fuel package has been adequately described and evaluated and that the package design meets the containment requirements of 10 CFR Part 71.

5.0 SHIELDING REVIEW

The contents consist of an unirradiated power unit. Shielding is not needed for the package to meet the external radiation standards in 10 CFR 71.47.

6.0 CRITICALITY REVIEW

The objective of this criticality review is to verify that the amendment to the S-6213 PUSC package design satisfies the criticality safety requirements of 10 CFR Part 71, including performance under the normal conditions of transport specified in 10 CFR 71.71 and the hypothetical accident conditions specified in 10 CFR 71.73. The major change related to the criticality evaluation was the addition of a new fuel assembly design as authorized contents, with an associated change in the internal configuration.

6.1 Model Evaluation

The applicant used an in-house Monte Carlo neutron transport theory computer program for all criticality calculations. This program allows for explicit representation of the fuel geometry and accurately models fuels, poisons, and accounts for self-shielding. This program also uses standard material definitions consistent with American Society of Mechanical Engineers and ASTM international standards. Neutron cross-sections are derived from Naval Reactors benchmarks and industry standard sources. All models used appropriately conservative assumptions for fuel loading and dimensional tolerances, and accounted for all biases and uncertainties. The applicant provided a list of applicable benchmarks to determine bias and uncertainty of the software used. Benchmark problems were chosen due to similarities in fissile and structural materials as well as assembly configuration.

6.2 Single Package Evaluation and Normal Conditions of Transport

The applicant did not perform explicit single package evaluations for normal conditions of transport and hypothetical accident conditions for the addition of the new fuel assembly design. The criticality for a single package is shown to be bounded by the hypothetical accident conditions model, which consist of an array of only a single package, since the criticality safety index used by the applicant is 100 and therefore only one package is allowed to be shipped at a time.

The applicant specified a criticality safety index of 100; therefore, calculations were performed using an array of three packages with no moderation for normal conditions of transport in accordance with 10 CFR 71.59(a)(1). The packages were modeled in a triangular array and reflected with at least 12 inches of water and were shown to be subcritical.

6.3 Hypothetical Accident Conditions

Hypothetical accident conditions are evaluated using the most reactive amount of credible changes in fuel configuration, control rod dimensions, and poison loading with the maximum amount of credible moderation under flooding conditions. Hypothetical accident conditions also account for any potential fuel assembly or control rod movement within the constraints of the package, and are shown to be subcritical. This evaluation bounds the single package evaluation required by 10 CFR 71.55(d) and (e).

The staff verified that the applicant's evaluation demonstrates that a single package is subcritical under both normal conditions of transport and hypothetical accident conditions. Consistent with a criticality safety index of 100, a single package was evaluated under hypothetical accident conditions in accordance with 10 CFR 71.59(a)(2) and shown to be subcritical.

6.4 Evaluation Findings

The staff reviewed the description of the S-6213 PUSC package and the allowable contents as they related to criticality safety and found them to be acceptable. Based on its review, the staff determined that the methods used in the criticality analyses are consistent with accepted industry practices and standards, and that the results are acceptable.

Based on its review of the statements and representations in the application, as supplemented, the staff concludes that the S-6213 package has been adequately described and evaluated, and that the package meets the standards for shipment under 10 CFR Part 71.

7.0 OPERATING PROCEDURES

Minor changes were made to the operating procedures to include the S9G power unit containing a VAFF core and ensure clarity.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

Minor changes were made to the acceptance tests and maintenance program to include the S9G power unit containing a VAFF core and ensure clarity.

CONDITIONS

The following changes have been made to the certificate:

Condition 5.(b)(1)(iii) and (2) has been added to specify the new contents.

The references section has been updated to include the supplements dated June 22, 2015, and April 13, 2016.

CONCLUSION

Certificate of Compliance No. 9186 has been revised to add an unirradiated S9G power unit containing the Virginia Forward Fit (VAFF) core as authorized contents in the Model Nos. Model 1, S-6213 Power Unit Shipping Container and Model 2, S-6213 Power Unit Shipping Container. Based on the statements and representations in the application, and with the conditions listed above, the staff agrees that this amendment does not affect the ability of the package to meet the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9186, Revision No. 17, for the Model Nos. Model 1, S-6213 Power Unit Shipping Container and Model 2, S-6213 Power Unit Shipping Container,
On July 25, 2016.