SAFETY EVALUATION REPORT

Docket No. 71-9186
Model No. S-6213 Power Unit Shipping Container
Certificate of Compliance No. 9186
Revision No. 15

SUMMARY

By application dated March 13, 2008, the U.S. Department of Energy, Division of Naval Reactors requested the U.S. Nuclear Regulatory Commission (NRC) issue an amendment to Certificate of Compliance (CoC) No. 9186 for the S-6213 package.

CoC No. 9186 includes two models of the S-6213 package. The Model 1 S-6213 package was fabricated prior to the 1983 edition of 10 CFR Part 71 and has a Package Identification Number Suffix designation of B( )F. Packages with the B( )F designation expired on October 1, 2008, in accordance with regulations in 10 CFR Part 71 and as stated in the current CoC, unless the package Safety Analysis Report is updated for the current applicable requirements. In the amendment request, the applicant requested to change the Package Identification Number Suffix designation to B(U)F-96. In accordance with 10 CFR 71.19(e), the applicant submitted information to show that the package meets the current regulatory requirements. To support the request, the applicant provided a fracture toughness evaluation to show compliance with the applicable changes from B( )F to B(U)F. The applicant also provided an evaluation of the package to the revised 10 CFR Part 71 regulations to justify the "-96" designation.

Based on the statements and representations in the application, and for the reasons stated in this Safety Evaluation Report, the staff finds that these changes do not affect the ability of the package to meet the requirements of 10 CFR Part 71.

EVALUATION FOR THE UNILATERAL ("U") DESIGNATION

In the amendment request, the applicant requested to change the Package Identification Number suffix designation to B(U)F-96. With respect to this package design, the change in the regulatory requirements for Fissile Type B Packages to a Unilateral ("U") designation, is the evaluation of the material fracture toughness for the package construction materials, considering the initial conditions temperatures described in 10 CFR 71.73(b). The applicant submitted a material fracture toughness evaluation in accordance with the current regulatory requirements in 10 CFR Part 71.

1. Introduction

The Model 1 S-6213 shipping package is a power unit shipping container (PUSC), which contains a new naval reactor vessel with fresh (unirradiated) fuel and control components installed. The Model 1 S-6213 package was constructed at a time before the regulations specified initial conditions for hypothetical accident conditions. Previous staff reviews have found the Model 1 S-6213 design to be acceptable without consideration of brittle fracture performance of the shipping package materials.

To upgrade the CoC to a "B(U)F" designation for the existing Model 1 S-6213 package, the materials of construction must be evaluated for compliance with the initial conditions specified in 10 CFR 71.73(b), and specifically, the requirements for brittle fracture resistance. Two Model 1

S-6213 packages exist and must be evaluated against the current fracture toughness criteria in order to remain in service beyond September 30, 2008, in accordance with 10 CFR 71.19(a)(3).

The Model 1 S-6213 package is not designed to be a radiological containment boundary under 10 CFR Part 71 regulations. The package is a secondary (non-radiological) enclosure for the PUSC cargo, which consists of the reactor fuel and associated control components. The primary barrier for the prevention of release of radioactive materials is the fuel cladding, which is typical for a fresh fuel package. Consequently, the fuel is analyzed against all required Part 71 design conditions of transport, including design accident conditions. However, as a secondary enclosure, the Model 1 S-6213 package must withstand the Part 71.73 hypothetical accident conditions which include resisting the effects of cold temperatures.

The Part 71.73 accident condition tests specify testing a transportation package design at the most unfavorable temperature between negative 20 degrees Fahrenheit (F) and positive 100 degrees F. It is commonly recognized that ferritic materials (i.e., carbon steels) may be susceptible to embrittlement under cold conditions. Thus, the negative 20 degrees F temperature becomes the most unfavorable condition for determining the performance of the package under the impact loading conditions that would result from a hypothetical accident.

2. Materials of Construction

The Model 1 S-6213 package was constructed of 3 different steels, which now require assessment in order to comply with current regulations. The package was constructed in accordance with United States Department of Defense standards called military-specifications (MIL-Specs), which imposed one or more requirements for fracture toughness (resistance to brittle fracture under cold conditions) as verified in the purchase orders for these materials. The MIL-Spec requirements, under which the package was constructed, comply with one or more of the criteria in NRC Regulatory Guide 7.11 (RG 7.11) (Reference 1). RG 7.11 outlines fracture toughness criteria for Category III shipping packages which do not perform a containment function. Meeting one or more of those criteria would satisfy the RG 7.11 criteria and demonstrate ability of the materials to withstand the Part 71.73 accident conditions at the most unfavorable temperature.

Considered separately, MIL-Specs and purchase order requirements do not provide adequate evidence of compliance with the fracture toughness requirement. Tests of archived material samples, or, certified material test reports or other documents provided at the time of material delivery can demonstrate the conformance of the actual materials of construction with the current 10 CFR 71.73 requirements. The applicant provided information from several sources to demonstrate that the materials could withstand the hypothetical accident conditions specified in 10 CFR 71.73. Specifically, the applicant provided information from tests of archived material samples and also presented archived documents with other evidence of compliance with fracture toughness requirements.

3. Materials Evaluation

Per the guidance of RG 7.11, for Category III (non-containment) service, materials less than 4 inches but greater than 0.4 inches thick must meet any one of the following criteria to assure adequate fracture toughness:

- Nil-Ductility Transition Temperature (NDTT) less than or equal to 10 degrees F, as measured by Drop Weight Testing or Dynamic Tear Testing (not by Charpy V-notch testing).
- Charpy V-notch Test Energy (CVN) greater than or equal to 15 ft-lb at 10 degrees F.
- Material manufactured to a Fine Grain Practice (FGP) microstructure.

There are 14 brittle fracture susceptible PUSC components in the subject thickness range. One was made from one ASTM grade of steel, the others were fabricated from a MIL-Spec steel.

Six different material heats were used to fabricate nine of the MIL-Spec grade steel components. For these components, the steel was produced to a FGP and the steel was also originally tested for NDTT. The measured NDTT was negative 40 degrees F. This demonstrates that the material significantly exceeded the requirements of RG 7.11 for fracture toughness.

As-built materials fracture toughness properties for the five components fabricated from the remaining heats of the MIL-Spec steel and the ASTM grade steel are not retrievable. These materials were evaluated without as-built properties by reviewing brittle fracture requirements from the materials ordering specifications. The applicant also provided administrative certification statements verifying that the materials meet the ordering requirements.

In this evaluation process, the material fabrication document files were reviewed to ensure that the fracture toughness specification was not degraded (altered) during the materials inspection and acceptance process. Such a deviation from the specification would have generated a non-conformance report and associated disposition report. Absent such evidence of a deviation from the specification requirements, it is reasonable to conclude that the subject materials fracture toughness would be similar to that for the heats of material for which records still exist.

The Model 1 S-6213 package has five heavy-section components made from materials which are potentially susceptible to brittle fracture. They have a nominal thickness ranging from 6.44 to 16.75 inches. These components are fabricated from one MIL-Spec grade of steel or one ASTM grade of steel.

RG 7.12 (Reference 2) “Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Wall Thickness Greater than 4 Inches (0.1 m) But Not Exceeding 12 Inches (0.3 m),” contains the appropriate guidance for these package materials. RG 7.12 does not contain fracture toughness criteria for ferritic steel shipping container materials greater than 4 inches thick that are classified as Category III (non-containment), so appropriate discretion must be applied for this situation. RG 7.12 communicates that materials must possess sufficient toughness to arrest through thickness flaws under dynamic loading conditions with stress levels as high as the material’s yield stress, and at a temperature as low as the package lowest shipping temperature (LST). Such criteria are typically applied to the containment boundaries of shipping canisters designed to handle the most highly radioactive materials such as spent nuclear fuel.

According to the NUREG/CR-1815 (Reference 3) and RG 7.12 criteria, a material must have a dynamic fracture toughness of around 140 kilopounds per square inch (ksi)-inches$^{1/2}$ at the LST of negative 20 degrees F. To meet this, thick-section steels typically must have an NDTT in the range of negative 135 degrees F. RG 7.12 provides a table of the required NDTT for thicknesses of 4 to 12 inches.

To meet the RG 7.11, Category III, fracture toughness criteria, the material must have an NDTT below 10 degrees F for sections up to 4 inches thick. This would result in a dynamic fracture toughness of about 35 to 40 ksi-inches$^{1/2}$ at the design LST of negative 20 degrees F. To account for the necessary change in NDTT for any package components greater than 4 inches thick, the applicant noted the difference in required NDTT for the sections heavier than 4 inches could be determined from RG 7.12, Table 1. The specified NDTT for heavier sections were simply subtracted from the value for the 4 inch thick material. These various differences were then subtracted from the 10 degree F requirement of RG 7.11. The new NDTT for each section thickness heavier than 4 inches was plotted to obtain a thickness-required NDTT curve. The resulting curve was based upon the 4-inch thickness requiring an NDTT of 10 degrees. The thicker sections require a somewhat lower NDTT. Thus, subtracting to account for the lower required NDTT for a heavier section, a 12 inch section for example would have a required NDTT of about negative 10 degrees F. The resulting curve was extrapolated to heavier sections (beyond the 12 inch limit of RG 7.12) and the required NDTT for the heavier sections was thereby determined from this curve extrapolation.

Having extrapolated the equivalent of Category III brittle fracture criteria for heavier sections, these criteria are used for comparison with the material's ordering specification. If the comparison shows the thick section fracture toughness properties being equal to or better than the extrapolated brittle fracture criteria, then the components are considered acceptable for the RG 7.11, Category III, brittle fracture criteria.

The MIL-Spec steel was used for some components up to 17 inches thickness. Based upon the extrapolated Category III NDTT curve, the NDTT for components up to this thickness would need to be negative 12 degrees F (or lower) in order to assure adequate fracture toughness. The MIL-Spec material's ordering specification required an NDTT of no higher than negative 40 degrees F. Thus, the specification requires an NDTT that is 28 degrees F below the extrapolated maximum NDTT of negative 12 degrees F. The specified NDTT is also 20 degrees below the LST of negative 20 degrees F.

No documents were available which directly reported this material's actual NDTT value. However, an administrative compliance document was available which indicated that each requirement of the ordering specification (MIL-Spec) was met. The document stated that no nonconformances were reported. Thus it is concluded that the MIL-Spec material possesses sufficient fracture toughness to meet the extrapolated Category III brittle fracture criteria.

The component fabricated from the ASTM grade material also lacks direct evidence of its NDTT. However, this particular grade of steel has been much studied by researchers in the field of brittle fracture and curves/tables of its properties are available in the open literature. A review of pertinent open literature revealed a reliable reference authored by W.S. Pellini, (Reference 4) which contained the results of numerous tests of this particular ASTM steel grade. This reference establishes an upper bound of NDTT for this material which is based upon testing of multiple heats of material. A conservative maximum NDTT value of negative 30 degrees F was established for this particular material. This is also below the LST. The extrapolated Category III maximum allowable NDTT for any component up to 20 inches thick (worst case) is approximately negative 14 degrees F. Thus, it may be concluded that the ASTM material possesses sufficient fracture toughness to meet the extrapolated Category III brittle fracture criteria.

The brittle fracture resistance of the welds (weld metal, heat affected zone) was specified to meet the criteria of NUREG/CR-3019 (Reference 5), paragraph 4.10, which states the welds

must meet the fracture toughness criteria of the base materials being joined. This must be demonstrated through fracture toughness testing of the welding procedure qualification coupons. The welds are shown to be in compliance with the procurement specifications by means of the weld procedure and qualification test results. Therefore, the welds of the PUSC meet the Category III brittle fracture requirements for the base materials and are acceptable.

4. Conclusion

The staff finds there is reasonable assurance that the materials and welds used to construct the two Model 1 S-6213 transportation packages meet the current brittle failure criteria of 10 CFR Part 71.

EVALUATION FOR THE -96 DESIGNATION

The applicant requested an amendment to Certificate of Compliance No. 9186 to revise the package identification number from USA/9186/B( )F to USA/9186/B(U)F-96, as specified in 10 CFR 71.19(e). To support its request for the "-96" designation, the applicant provided a table addressing the 19 issues considered in the rulemaking process that resulted in the revised rule, which was published on January 26, 2004 (69 FR 3698). The staff evaluated the applicant's request, as described below.

- Issue 1, Changing Part 71 to the International Systems of Units (SI) Only. This proposal was not adopted in the final rule, and therefore no changes were needed in the package application or the Certificate of Compliance to conform to the new rule.

- Issue 2, Radionuclide Exemption Values. The final rule adopted radionuclide activity concentration values and consignment activity limits in TS-R-1 for the exemption from regulatory requirements for the shipment or carriage of certain radioactive low-level materials. In addition, the final rule adopted an exemption from regulatory requirements for certain natural material and ores containing naturally occurring radionuclides. The applicant stated that this revision was not applicable to the S-6213 package. The staff agrees, based on the design purpose of the S-6213 package and the allowed contents specified in the certificate. Thus, no changes were needed to conform to the new rule.

- Issue 3, Revision of A_1 and A_2. The final rule adopted changes in the A_1 and A_2 values from TS-R-1, with the exception of two radionuclides. The A_1 and A_2 values were modified in TS-R-1 based on refined modeling of possible doses from radionuclides, and the NRC agreed that incorporating the latest in dosimetric modeling would improve transportation regulations. The applicant stated that this change was not applicable to the S-6213 package, since it is shown to be leak tight. The containment analysis was not based on the A_2 values in Part 71. Thus, no changes were needed to conform to the new rule.

- Issue 4, Uranium Hexafluoride (UF6) Package Requirements. The S-6213 package is not authorized for the transport of uranium hexafluoride. Therefore, no changes were needed to conform to the new rule.

- Issue 5, Criticality Safety Index (CSI). The final rule adopted the new term Criticality Safety Index from TS-R-1. The NRC previously evaluated and resolved this issue with this package, which was issued in a CoC renewal on March 26, 2007. The current CoC

specifies a CSI, which is based on calculations in the package Safety Analysis Report. No changes were needed to conform to the new rule.

- Issue 6, Type C Packages and Low Dispersible Material. This proposal was not adopted for the final rule. Thus, no changes were needed.

- Issue 7, Deep Immersion Test. The final rule adopted an extension of the previous version of 10 CFR 71.61 from packages for irradiated fuel to any Type B package containing activity greater than 10^5 A_2. The 10^5 A_2 value for radionuclides contained in the S-6213 package is greater than the total activity stated in the package Safety Analysis Report. Therefore, the deep immersion test is not applicable to the S-6213 package. Thus, no changes were needed to conform to the new rule.

- Issue 8, Grandfathering Previously Approved Packages. The final rule adopted a process for allowing continued use, for specific periods of time, of previously approved package designs without demonstrating compliance to the final rule. Grandfathering provisions for continued use of the Model 1 S-6213 package, which is designated as a B( )F package type, expire on October 1, 2008. The applicant has decided in accordance with 10 CFR 71.19(e) to submit information demonstrating compliance with the revised rule. Thus, grandfathering the design of the S-6213 package is not necessary.

- Issue 9, Changes to Various Definitions. The final rule adopted several revised and new definitions. These changes were adopted to provided clarity to Part 71. Thus, no changes were needed to conform to the new rule.

- Issue 10, Crush Test for Fissile Material Packages. The revised 10 CFR 71.73 expanded the applicability of the crush test to fissile material packages. The crush test is required for packages with a mass not greater than 500 kilograms (1100 pounds). Since the S-6213 package has a mass greater than this, the crush test is not applicable. Therefore no changes were needed to conform to the new rule.

- Issue 11, Fissile Material Package Design for Transport by Aircraft. The final rule adopted a new section, Section 71.55(f), which addresses design requirements for packages transporting fissile material by air. The applicant stated that this requirement is not applicable to the S-6213 package, since fissile materials will not be transported by air. Therefore, for clarity, the CoC has been revised to specify that air transport is not authorized for fissile material.

- Issue 12, Special Package Authorization. The final rule adopted provisions for special package authorization that will apply only in limited circumstances and only to one-time shipments of large components. This provision is not applicable to the S-6213 package. Thus, no changes were needed to conform to the new rule.

- Issue 13, Expansion of Part 71 Quality Assurance (QA) Requirements to Certificate Holders. The final rule expanded the scope of Part 71 to apply to any person holding or applying for a CoC. Quality assurance requirements apply to design, purchase, fabrication, handling, shipping, storing, cleaning, assembly, inspection, testing, operation, maintenance, repair, and modification of components of packaging that are important to safety. The applicant stated that the naval nuclear propulsion program quality assurance program satisfy the current requirements of 10 CFR 71, Subpart H,

Quality Assurance. Additionally, these NRC requirements do not apply in this situation since DOE is not covered under the statutory authority of the NRC. No further changes were needed to conform to the new rule.

- Issue 14, Adoption of the American Society of Mechanical Engineers (ASME) Code. This proposal was not adopted in the final rule. Thus, no changes were needed to conform to the new rule.

- Issue 15, Change Authority for Dual-Purpose Package Certificate Holders. This proposal was not adopted for the final rule. Thus, no changes were needed to conform to the new rule.

- Issue 16, Fissile Material Exemptions and General License Provisions. The final rule adopted various revisions to the fissile material exemptions and the general license provisions in Part 71 to facilitate effective and efficient regulation of the transport of small quantities of fissile material. The criticality safety of the S-6213 package does not rely on limiting fissile materials to exempt or generally licensed quantities. The package Safety Analysis Report demonstrates criticality safety of the package with the authorized fissile contents. Therefore, no changes were needed to conform to the new rule.

- Issue 17, Double Containment of Plutonium. The final rule removed the requirement that packages with plutonium in excess of 0.74 terabecquerel (20 curies) have a second, separate inner container. The S-6213 package is not authorized to carry Plutonium. Thus, no changes were needed to conform to the new rule.

- Issue 18, Contamination Limits as Applied to Spent Fuel and High Level Waste Packages. This proposal was not adopted for the final rule. Thus, no changes were needed to conform to the new rule.

- Issue 19, Modification of Events Reporting Requirements. The final rule adopted modified reporting requirements. The applicant stated that the naval nuclear propulsion program quality assurance program satisfy the current requirements of 10 CFR Part 71, Subpat H, Quality Assurance. Additionally, these NRC requirements do not apply in this situation since DOE is not covered under the statutory authority of the NRC. No further changes were needed to conform to the new rule.

The staff has reviewed the 19 issues considered in the rulemaking process that resulted in the revised rule of 10 CFR Part 71 and concludes that the S-6213 package design has been adequately described and meets the requirements of the revised regulations in 10 CFR Part 71.

Changes to Certificate of Compliance

The CoC has been updated to reflect changes associated with Revision No. 15 and includes the following:

- The package identification number has changed to designate the package as B(U)F-96. The preceding review has shown that the Model 1 S-6213 package meets the current regulations and thus is designated as a B(U)F-96 package.

- Condition No. 6 was deleted, which previously allowed the use of the Model 1 of the S-6213 package until October 1, 2008. The preceding review has shown that the

Model 1 S-6213 package meets the current regulations and thus is designated as a B(U)F-96 package.

- Condition No. 7 was added to indicate air transport of fissile material is not authorized due to the package not being evaluated against the requirements in 10 CFR 71.55(f).

- As a consequence of the inclusion of the new Condition No. 7, the previous Condition No. 7 was renumbered No. 6.

- Condition No. 9 was deleted due to the grandfathering provision expiring on October 1, 2008. The use of the previous revision of this CoC would be in violation of the current regulations, therefore the current revision of this CoC is the only one that can be used.

- As a consequence of the deletion of the previous Condition No. 9, the previous Condition No. 10 was renumbered No. 9.

- The March 13, 2008, submittal was included in the References section.

CONCLUSION

Based on the statements and representation in the application, the staff concludes that the S-6213 package meets the requirements of the revised 10 CFR Part 71 and the revised CoC is effective immediately.

REFERENCES

1) Regulatory Guide 7.11 “Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Maximum Wall Thickness of 4 Inches.”

2) Regulatory Guide 7.12 “Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Wall Thickness Greater than 4 Inches But Not Exceeding 12 Inches.”

3) NUREG/CR-1815, Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers Up to Four Inches Thick, dated August 1981.

4) Guidelines for Fracture-Safe and Fatigue-Reliable Design of Steel Structures: by William S. Pellini; produced and distributed by: The Welding Institute, Abington Hall, Cambridge CB1 6AL England, copyright 1983.

5) NUREG/CR-3019; Recommended Welding Criteria For Use in the Fabrication of Shipping Containers for Radioactive Materials; dated March 1984.

Issued with Certificate of Compliance No. 9186, Revision No.15 on: November 6, 2008.