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Washington, DC 20555

SHIPPING CONTAINERS - TOPICAL REPORT ON REGULATORY GUIDANCE FOR TYPE B TRANSPORTATION PACKAGES WITH A MODERATOR EXCLUSION SAFETY BASIS; REQUEST FOR NUCLEAR REGULATORY COMMISSION REVIEW AND CONCURRENCE

Background: Naval spent fuel shipping containers are designed to meet the Type B Package requirements for shipment of fissile and highly radioactive material in accordance with Title 10, Code of Federal Regulations, Part 71 (10CFR71). Naval Reactors (NR) independently certifies Type B packages used in the Naval Nuclear Propulsion Program (NNPP) to 10CFR71 as part of the Department of Energy (DOE) in accordance with 49CFR173.7.(d). 10CFR71 requires that a package is subcritical under the prescribed hypothetical accident conditions assuming that water moderation occurs to the most reactive credible extent consistent with the damaged condition of the package. Historically, NNPP Type B safety analysis reports for packaging have demonstrated compliance with this requirement by assuming the package is either fully or preferentially flooded with water, even if flooding is not expected. However, compliance with 10CFR71 can be demonstrated by showing that water does not flood the package under hypothetical accident conditions, such that water moderation is not credible.

Discussion: Enclosure (1) of this letter forwards a topical report on regulatory guidance for licensing NNPP Type B packages using a moderator exclusion safety basis to demonstrate compliance with 10CFR71. The guidance is based on current regulatory requirements, guidance, and precedent set in the commercial industry, and requires that NNPP Type B packages include at least two separate, enclosing barriers that surround the package contents and are each demonstrated to remain watertight under normal and accident conditions of 10CFR71.

Naval Reactors desires to obtain alignment with the NRC on application of moderator exclusion guidance to DOE-NR certified packages because (1) alignment is warranted on whether NRC guidance with respect to moderator exclusion can apply to packages

containing Naval fuel, (2) independent NRC technical review is warranted of proposed DOE-NR regulatory guidance with respect to compliance with NRC regulations, and (3) future shipments of spent fuel to interim or permanent repositories will require NRC-licensing of transportation packages in accordance with the Nuclear Waste Policy Act (as amended).

Request for Action: Naval Reactors requests NRC review and concurrence with the topical report on moderator exclusion guidance, provided in Enclosure (1). To support planned development of the packages with moderator exclusion, Naval Reactors requests NRC schedule your review to complete by May 2025.

If you have any questions, please do not hesitate to call me at (202) 781-6034.

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N. S. Plate
Naval Reactors

Enclosure: (1) DOE-NR Regulatory Guidance for Licensing Transportation Packages Containing Fissile Material with Moderator Exclusion Safety Basis

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ENCLOSURE (1)

DOE-NR Regulatory Guidance for Licensing Transportation Packages Containing Fissile Material with Moderator Exclusion Safety Basis

DOE-NR Regulatory Guidance for Licensing Transportation Packages Containing Fissile Material with Moderator Exclusion Safety Basis (PROPOSED) (U)

Prepared for:
Naval Reactors
By Naval Nuclear Laboratory.
Under Contract No. 89233018CNR000004

1 INTRODUCTION AND MOTIVATION

Naval Reactors (NR) independently certifies shipping containers for transportation in accordance with Title 49, Code of Federal Regulations, Part 173 (49 CFR 173). NR designs spent fuel shipping containers to meet the Type B package requirements for shipment of fissile and highly radioactive material in accordance with 10 CFR 71.

The provisions of Title 10, Part 71 of the Code of Federal Regulations (10 CFR 71) Section 55(e), require a fissile material package to demonstrate sub-criticality assuming water moderation occurs to the most reactive credible extent, consistent with the damaged condition of the package and the chemical and physical form of the contents. The Department of Energy Division of Naval Reactors (DOE-NR) has treated moderation to the "most reactive credible extent" as either full or preferential flooding of the package, whichever is more reactive.

Embrittlement of zirconium alloys used in nuclear fuels can result in less robust structural performance of these fuels at end of life when subject to the §71.73 hypothetical accident condition (HAC) tests. This less robust structural performance can result in reconfiguration of the fissile contents within a package, complicating demonstrations of compliance with the requirements of §71.55(e). DOE-NR desires to formalize guidance for use in developing 10 CFR 71 license applications that limit the moderation considered in §71.55(e) evaluations based on the damaged condition of the container; specifically, excluding moderation for §71.55(e) evaluations in cases where the package can be definitively demonstrated to prevent leakage of water into the containment barrier prior to, during, and following the §71.73 HACs. This guidance will simplify the preparation of license applications and result in applications that are more resilient to changes in the predicted performance of the fissile material cargo.

Implementation of moderation exclusion has only been provided by the Nuclear Regulatory Commission (NRC) through regulatory guidance and has not been codified into 10 CFR 71. DOE-NR desires to obtain alignment with the NRC regarding application of moderator exclusion guidance to DOE-NR certified packages because: 1) it is unclear if existing NRC guidance with respect to moderator exclusion should be considered for packages containing Naval fuel; 2) DOE-NR desires an independent technical review of proposed DOE-NR regulatory guidance with respect to compliance with NRC regulations; and 3) the Nuclear Waste Policy Act (NWPA), Subtitle H, §180(a) (Reference (a)), requires shipments of SNF to interim or permanent repositories to be made using NRC-licensed packages.

The guidance proposed herein does not relate to the evaluation of undamaged packages in accordance with §71.55(b). The proposed DOE-NR regulatory guidance is applicable only to the aspects of 10 CFR 71.55(e) regarding moderator exclusion, and does not relieve demonstration of compliance to the remainder of 10 CFR 71. All DOE-NR SNF packages are loaded in flooded conditions (and drained prior to shipment) and as a result, DOE-NR intends to assume flooding in demonstrating compliance to 10 CFR 71.55(b).

2 PROPOSED DOE-NR REGULATORY GUIDANCE

For compliance with 10 CFR 71.55(e) using moderator exclusion as a licensing basis, the following regulatory guidance shall only apply to DOE-NR fissile material transportation packages.

Package designs shall include at least two separate, enclosing barriers that surround the fissile contents; each barrier shall be demonstrated to remain watertight under normal and accident conditions. Watertight shall be defined as:

- meeting the definition of leak-tight in accordance with ANSI N14.5, or
- meeting a case specific leakage rate that demonstrates no intrusion of water (moderator) into the barriers.

Package barriers relied upon for moderator exclusion shall be leak rate tested to verify watertight criteria are met during the various phases of package fabrication and operation.

The structural performance of each barrier shall be evaluated under normal and accident conditions. The barrier closure system (e.g., sealing regions, closure fasteners, welds) shall be designed to remain elastic. If not practical to demonstrate elastic behavior, inelastic deformation is acceptable if the barriers can be demonstrated to remain watertight.

Drop testing of prototypic package models, in limiting orientations, shall be performed to demonstrate acceptable barrier behavior prior to and following accident conditions. Prototypic package models shall include (at a minimum) impact-mitigating devices, all package closure systems and sealing elements relied upon for moderator exclusion, and components (e.g., representative cargo) to ensure appropriate loading on limiting areas. The tests shall include leak rate testing prior and subsequent to drop tests of the package. As an alternative to prototypic physical drop testing, benchmarking to previous, similar packages, may be performed to demonstrate the validity of analytical drop test results.

3 TECHNICAL JUSTIFICATION OF DOE-NR REGULATORY GUIDANCE

Justification for the proposed regulatory guidance provided in Section 2 derives from three sources: existing regulation (NRC and International Atomic Energy Agency (IAEA)), existing regulatory guidance, and regulatory precedent. Existing NRC and IAEA requirements provide the framework within which the proposed guidance applies. Published NRC regulatory guidance illustrates the current review standard for 10 CFR 71 license applications by the NRC, and regulatory precedent (approved license applications) clarifies the application of existing NRC guidance. The proposed guidance presented herein aligns with present regulations, and is consistent with current NRC guidance and licensing actions.

3.1 APPLICABLE REGULATORY REQUIREMENTS

Two applicable sources of regulatory requirements exist: 10 CFR 71 from the NRC and SSR-6 from the IAEA. SSR-6 provides the framework that permits licensing of radioactive material transportation packages for international shipment. Periodically, the NRC amends 10 CFR 71 in order to harmonize its requirements with the requirements of SSR-6. Thus, it is appropriate to consider both regulatory documents in developing guidance for licensing applications in which post-accident criticality assessments will credit package moderator exclusion barriers.

Regulations that specify criticality safety requirements for fissile material packages are provided in 10 CFR 71.55. Section 71.55 addresses sub-criticality of a single package in isolation; specifically, §71.55(e) addresses the performance of a single package subject to the tests of §71.73 (HACs). IAEA SSR-6 includes provisions for fissile material packages that are similar, but not identical, to those in 10 CFR 71. Regulations that specify criticality safety requirements for fissile material package are SSR-6 Paragraphs 673 through 686. Paragraphs 680 through 682 specifically address sub-criticality of an individual package in isolation.

3.1.1 10 CFR 71.55 (2022 Edition)

Single package criticality performance requirements for packages subject to the §71.73 HACs are provided in §71.55(e). 10 CFR 71.55 (e) states that:

> *A package used for the shipment of fissile material must be so designed and constructed and its contents so limited that under the tests specified in §71.73 ("Hypothetical accident conditions"), the package would be subcritical. For this determination, it must be assumed that:*
>
> 1. *The fissile material is in the most reactive credible configuration consistent with the damaged condition of the package and the chemical and physical form of the contents;*
> 2. *Water moderation occurs to the most reactive credible extent consistent with the damaged condition of the package and the chemical and physical form of the contents; and*
> 3. *There is full reflection by water on all sides, as close as is consistent with the damaged condition of the package.*

The requirements of §71.55(e) identify that water moderation occurs to the extent "consistent with the damaged condition of the package". DOE-NR has implemented this requirement by performing evaluations that consider either full or preferential flooding of the package, regardless of whether the damaged configuration of the package would completely exclude the entry of water into the package. As written, the requirement appears to permit consideration that the package condition may prohibit ingress of water.

3.1.2 IAEA SSR-6, Sections 680-682 (2018 Edition)

Single package criticality performance requirements for fissile material packages are provided in Sections 680 through 683 of SSR-6 (Section 683 is relevant only to shipments by air, and is not reproduced herein since there is not applicability to DOE-NR packages):

SSR-6, Section 680 states that:

> *For a package in isolation, it shall be assumed that water can leak into or out of all void spaces of the package, including those within the containment system.*
> *However, if the design incorporates special features to prevent such leakage of water into or out of certain void spaces, even as a result of error, absence of leakage may be assumed in respect of those void spaces. Special features shall include either of the following:*
>
> *(a) Multiple high standard water barriers, not less than two of which would remain watertight if the package were subject to the tests prescribed in para. 685(b), a high degree of quality control in the manufacture, maintenance and repair of packagings, and tests to demonstrate the closure of each package before each shipment; or*
>
> *(b) For packages containing uranium hexafluoride only, with a maximum uranium enrichment of 5 mass percent uranium-235:*
>
> *(i) Packages where, following the tests prescribed in para. 685(b), there is no physical contact between the valve or the plug and any other component of the packaging other than at its original point of attachment and where, in addition, following the test prescribed in para. 728, the valve and the plug remain leak-tight;*

(ii) A high degree of quality control in the manufacture, maintenance and repair of packagings, coupled with tests to demonstrate closure of each package before each shipment.

SSR-6, Section 681 states that:

It shall be assumed that the confinement system is closely reflected by at least 20 cm of water or such greater reflection as may additionally be provided by the surrounding material of the packaging. However, when it can be demonstrated that the confinement system remains within the packaging following the tests prescribed in para. 685(b), close reflection of the package by at least 20 cm of water may be assumed in para. 682(c).

SSR-6, Section 682 states that:

The package shall be subcritical under the conditions of paras 680 and 681 and with the package conditions that result in the maximum neutron multiplication consistent with:

(a) *Routine conditions of transport (incident free);*
(b) The tests specified in para. 684(b);
(c) The tests specified in para. 685(b).

In the above, the tests of 684(b) correspond to Normal Conditions of Transport (NCOT) and the tests of 685(b) correspond to HACs.

The requirements reproduced above are largely consistent with the requirements of 10 CFR 71.55(e), with the notable difference that Section 680 of SSR-6 explicitly identifies conditions under which leakage of water into the package need not be evaluated. Beyond identifying that moderation be considered consistent with the damaged condition of the package, Section 680 identifies that the absence of leakage may be assumed if the package contains not less than two high standard water barriers that are tested prior to each shipment and remain water tight when subject to the NCOT and HAC tests. The principle of this approach is to provide assurance of moderator exclusion under NCOT and HACs through the use of redundant, high-confidence barriers to moderation whose performance is verified through physical tests and prior to each shipment.

3.2 EXISTING REGULATORY GUIDANCE

The NRC and the IAEA provide guidance related to their respective regulatory frameworks. In the case of the NRC, this guidance is made available in the form of Regulatory Guides and NUREGs. Guidance specifically tailored to NRC licensing reviewers is also provided in the form of Interim Staff Guidance (ISG) documents. The IAEA provides advisory material documents containing guidance and recommendations related to IAEA regulations in the form of Specific Safety Guides (SSGs). Review of this material supports the conclusion that full/preferential moderation of a package subject to the HAC tests is not required to demonstrate compliance to 10 CFR 71.

3.2.1 NUREG-2216 (2020 Edition)

NUREG-2216, Standard Review Plan (SRP) for Transportation Packages for Spent Fuel and Radioactive Material, provides regulatory guidance for review of transportation package license applications. This document incorporates guidance formerly provided in ISG-19 regarding §71.55(e) compliance for packages of high-burnup fuel from commercial light water reactors (for which end-of-life structural performance may be problematic, resulting in reconfiguration of the

fissile contents). Section 1.4 of NUREG-2216 identifies two broad safety basis approaches that may be employed to demonstrate §71.55(e) compliance for such fuels:

(1) The reconfigured fuel is subcritical even with water in-leakage, or
(2) The package excludes water under HACs.

The characteristics of each of these safety basis approaches is further refined in Table 1-2 of NUREG-2216, which is reproduced herein as Table 1. Table 1 reproduces only the portion of the table related to exclusion of water under HACs (denoted as option (2) previously).

Table 1: Excerpt from NUREG-2216, "Summary of Approaches for Demonstrating Subcriticality of SNF under the Requirements of 10 CFR 71.55(e)"
(Excerpted from Table 1-2 of NUREG-2216)

(2) Evaluations Based on Moderator Exclusion		
Approach	**Characteristics**	**Objective**
Criticality Assessment of Reconfigured Fuel Assuming Moderator Exclusion	1. Demonstrate watertight barrier under hypothetical accident conditions. 2. Perform drop test of package (i) OR inner canister (ii) as described below.	
(i) For Welded Canister-Based Systems: Canister Drop Test as Part of Impact Limiter Testing	1. Include scale model of canister and contents in transport package impact limiter 30-foot drop tests. 2. Perform relative leak-rate testing by testing before and after each drop. 3. Demonstrate leakage rate acceptable to prevent water inleakage.	Conduct physical test of scaled canister to provide added assurance of moderator exclusion under accident conditions.
(ii) For Canister-Based Systems and Direct-Loaded Packages: Bolt Closure System Test as Part of Impact Limiter Testing	1. Include transport package bolt closure system in scale model of package in 30-foot drop tests of the impact limiter. 2. Perform relative leak rate testing by testing before and after each drop. 3. Demonstrate leakage rate acceptable to prevent water inleakage.	Conduct physical test of scaled bolt closure system to provide added assurance of moderator exclusion under accident conditions.

Table 1 identifies a number of characteristics applicable to a moderator exclusion safety basis approach. These characteristics fall into two broad categories: 1) demonstrate the presence of a watertight barrier under HACs, and 2) validate this demonstration through physical scale model drop testing of the relevant barriers (including leak rate testing of those barriers). The evidence for demonstration of a watertight barrier is further described in later sections of NUREG-2216.

NUREG-2216, Section 2.4.6 (Hypothetical Accident Conditions) states that:

> *"[For a moderator exclusion approach], ensure that the applicant showed there would be no inelastic deformation of the containment closure system (e.g., bolt closure or welded region of a canister) under hypothetical accident conditions."*

NUREG-2216, Section 9.4.1.5 (Acceptance Tests) states that:

> *"…for spent fuel packages that rely on moderator exclusion to demonstrate compliance with 10 CFR 71.55(e), ensure that the application includes test that will adequately demonstrate that packaging components relied on as barriers to water in-leakage will perform as credited in the analysis (i.e., to criteria consistent with the evaluation to keep water out)..."*

NUREG-2216, Section 9.4.2.3 (Maintenance Program) states that:

> *"…for spent fuel packages that rely on moderator exclusion to demonstrate compliance with 10 CFR 71.55(e), ensure that the application includes test that will adequately demonstrate that packaging components relied on as barriers to water in-leakage will perform as credited in the analysis (i.e., to criteria consistent with the evaluation to keep water out)..."*

NUREG-2216 does not appear to require redundant independent barriers. The guidance presented therein does establish an expectation for physical, scale model testing of the credited water exclusion barrier and an absence of plastic deformation in the closure system of that barrier under HACs. The guidance also clarifies the expectation that the barriers to moderation are to be subject to regular testing to validate their performance.

3.2.2 SSG-26 (2018 Edition)

IAEA SSG-26, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, provides recommendations and guidance for achieving and demonstrating compliance with the safety requirements of IAEA SSR-6. As discussed in Section 3.1.2 of this document, Section 680(a) of SSR-6 allows for moderator exclusion during the criticality evaluation of a single package under HACs if specific conditions are satisfied. SSG-26 provides additional information regarding these conditions.

SSG-26, Section 680.1 (addressing SSR-6 Section 680) states that:

> *"…The presence of water may be excepted from those void spaces protected by special features that remain watertight under accident conditions of transport. Credible conditions of transport that might provide preferential flooding of packages leading to an increase in neutron multiplication should be considered…"*

SSG-26, Section 680.2 (addressing SSR-6 Section 680) states that:

> *"To be considered 'watertight' for the purposes of preventing in-leakage or out-leakage of water related to criticality safety, the effects of both the normal and accident condition tests need to be considered. Leakage criteria for water tightness should be established in the application for multilateral approval for each package design and accepted by the competent authority. These criteria should be demonstrated as being achievable in both the tests and in the production models."*

SSG-26, Section 680.5 (addressing SSR-6 Section 680) states that:

> *"The packaging components that are relied upon to preserve criticality safety should be explicitly defined. The packaging components that are relied upon to maintain containment and geometry control of the fissile material should comprise engineered features whose design is defined in the drawings of the packaging. These components should be included in any physical tests or engineering evaluations performed for the package for normal conditions of transport and hypothetical accident conditions, as applicable (see para. 681.1)."*

SSG-26, Section 681.2 (addressing SSR-6 Section 681) states that:

> *"The competent authority may also require the subcriticality of inner packaging components together with the fissile material from an individual package and with full water reflection under routine conditions of transport. This is to cover scenarios where the inner packaging components together with the fissile material may be removed from the packaging and would also apply to systems with multiple barriers."*

SSG-26, Section 682.1 (addressing SSR-6 Section 682) states that:

> *"The requirements for demonstrating subcriticality of an individual package are specified so as to determine the maximum neutron multiplication in both normal and accident conditions of transport. In the assessment, due account needs to be given to the result of the packages tests required in paras 684(b) and 685(b) of the Transport Regulations and the conditions under which the absence of water leakage may be assumed, as described in para. 680 of the Transport Regulations."*

The SSG-26 guidance, specifically Section 680.5, is similar to that of NUREG-2216 in that the water exclusion barriers (i.e., "packaging components relied upon to maintain containment") should be subject to physical testing to verify their performance under accident conditions. However, the IAEA allows engineering evaluations as an option to physical testing and, per SSR-6, Section 680 (a), requires at least two high standard water barriers.

3.3 REGULATORY PRECEDENT FOR MODERATOR EXCLUSION

Based on review of publicly available package application documents, a moderator-exclusion safety basis is known to have been employed to license two packages made by HOLTEC International, the HI-STAR 180 and HI-STAR 190. These examples illustrate the application of NRC guidance to the licensing of commercial SNF packages. For reference, the NRC Safety Evaluation Reports (SERs) for the HOLTEC HI-STAR 180 and HI-STAR 190 are contained in Reference (b) and Reference (c), respectively.

3.3.1 HOLTEC HI-STAR 180

The HOLTEC HI-STAR 180 package is a cylindrical metal cask with impact limiters on each end, engineered to serve as a type B(U)F-96 package to transport radioactive material including undamaged commercial SNF (moderately burned fuel (MBF), high burnup fuel (HBF)) and low to high level non-fuel waste. The design of the HOLTEC HI-STAR 180 features a double closure lid system (which is not categorized as a double barrier), internal fuel baskets, and does not consider water intrusion into the internals under HACs credible. The HOLTEC HI-STAR 180 package is certified to the safety standards of 10 CFR 71 under NRC docket number 71-9325.

During review of the HOLTEC HI-STAR 180 package application, the NRC staff noted several concerns with the package application relative to moderator exclusion. NRC guidance for

moderator exclusion (located in ISG-19 at the time of application review, currently located in NUREG-2216) requires drop testing of the closure systems to provide added assurance of moderator exclusion under HACs. HOLTEC did not drop test the closure system. In addition, the NRC staff identified that the double closure lid system was not considered a redundant barrier under IAEA regulations and, given the lack of physical testing, that additional rationale and supporting justification would be required to justify the approach taken in the package application (Reference (d)). Further, the NRC staff emphasized that the guidance for moderator exclusion is focused on providing alternatives to maintaining SNF geometries, not the basket geometry. Therefore, HOLTEC must demonstrate the structural and geometric integrity of the baskets under the most adverse structural and thermal environment as a result of regulatory NCOT and HACs (Reference (e)).

HOLTEC committed to demonstrate defense-in-depth by including a detailed analysis with reconfigured SNF coincident with flooding of the cask (Reference (d)) to resolve the concerns introduced by the NRC staff regarding moderator exclusion. In addition, HOLTEC demonstrated that the internal basket stays intact for both NCOT and HACs. These analyses were included in the Reference (f) Safety Analysis Report (SAR).

3.3.2 HOLTEC HI-STAR 190

The HOLTEC HI-STAR 190 package is a cylindrical metal cask with impact limiters on each end, engineered to serve as a type B(U)F-96 package to transport radioactive material including undamaged commercial SNF (MBF and HBF), reactor related non-fuel waste, and high level non-fuel waste. In addition, the HI-STAR 190 package includes a multi-purpose canister (MPC) internal to the metal cask. Unlike the HI-STAR 180, the design of the HI-STAR 190 features a redundant watertight barrier provided by the metal cask and the MPC. As a result of the redundant barrier system, the HI-STAR 190 package does not consider water intrusion of the internals under HACs credible. The HOLTEC HI-STAR 190 package is certified to the safety standards of 10 CFR 71 under NRC docket number 71-9373.

During review of the HOLTEC HI-STAR 190 package application, the NRC staff noted a concern with the package application relative to the drop testing conducted by analysis (Reference (g)). In order to demonstrate compliance to 10 CFR §71.71 (“Normal Conditions of Transport), §71.73 (“Hypothetical Accident Conditions”), and §71.61 (“Special Requirements for Type B Packages Containing more than 10^5 A_2”), the effects on a package must be evaluated by subjecting a specimen or scale model to a specific test, or by another method of demonstrating compliance as deemed acceptable by the NRC (10 CFR §71.41(a)). Without providing the basis of their analytical testing results, HOLTEC did not demonstrate that the features relied upon for moderator exclusion would perform as intended.

The licensing basis for the HOLTEC HI-STAR 190 package structural performance is based on benchmarked analytical modeling in lieu of physical testing (Reference (c)). HOLTEC used a half-symmetry LS-DYNA model to represent the HI-STAR 190 package and conducted the tests prescribed in 10 CFR §71.71 and §71.73 analytically. To validate the modeling approach, HOLTEC conducted benchmarking (based on physical drop testing of models representative of the HI-STAR 100 container) in order to justify that impact events could be accurately represented in LS-DYNA. Through additional testing and validations with known drop tests (DOE Multi-Canister Overpack (MCO)) and ANSYS simulations (HI-STAR 60, 180, and 180D), HOLTEC justified the use of LS-DYNA for the prediction of peak decelerations and structural responses. Based on the benchmarking of LS-DYNA and the ability to model package behavior

similar to the HI-STAR 190, the analytical approach to impact analysis was accepted in accordance with 10 CFR 71.41.

As mentioned previously, the HI-STAR 190 features redundant watertight barriers provided by the transport cask and MPC. As a result of the redundant barrier system, the HI-STAR 190 package does not consider water intrusion of the internals under HACs credible. Therefore, the criticality analyses of the package under HACs performed in the Reference (h) SAR do not consider water moderation in the inner barrier. As a defense-in-depth, the Reference (h) SAR includes a limited number of criticality evaluations with major reconfigured SNF and moderation of the inner barrier under HACs, which show the reactivity of the package remains subcritical. The calculated reactivity of these evaluations showed a maximum effective neutron multiplication factor (k_{eff}) of 0.98. In Section 6.3 in NUREG-2216, the NRC establishes a limit to the k_{eff} at 0.95 as guidance for demonstrating subcriticality of fissile material transportation packages. In response to these defense-in-depth calculations and the use of 0.98 as a reactivity limit, Section 6.6.2 of the Reference (d) NRC safety evaluation report states:

> *Also, the [high burn-up fuel] major reconfiguration analysis is an additional analysis to demonstrate subcriticality under a low likelihood scenario where fuel reconfigures into a more reactive condition with water in-leakage, and is not intended to satisfy any particular 10 CFR Part 71 criticality safety requirement. Therefore, the staff finds the applicant's use of a 0.98 k_{eff} limit acceptable for this additional analysis.*

3.4 JUSTIFICATION OF PROPOSED DOE-NR REGULATORY GUIDANCE

The following discussion demonstrates how the proposed DOE-NR regulatory guidance meets existing regulations and guidance, and thus provides an appropriate basis for future licensing based on a moderator exclusion safety basis for DOE-NR fissile packages. The proposed DOE-NR regulatory guidance is applicable only to the definition of moderation "consistent with the damaged condition of the package" as discussed in 10 CFR 71.55(e)(2).

The DOE-NR regulatory guidance is consistent with 10 CFR 71.55(e)(2), as the guidance provides clarity regarding specific criteria that must be met in order to credit the "damaged condition of the package" with excluding moderation from the region containing the fissile contents. Specifically, the guidance implements the guidelines from Table 1-2 of Section 1.4.4 of NUREG-2216 requiring demonstration of the moderation barrier and physical drop testing (also consistent with Section 680.5 of IAEA SSG-26). The DOE-NR guidance extends that of NUREG-2216 to require the presence of at least two moderator barriers in a package design, consistent with Section 680 of IAEA SSR-6, which requires the presence of redundant high-confidence barriers.

Since some package designs may be well benchmarked by physical testing performed for other packages, the DOE-NR guidance allows physical testing of the moderator barrier to be replaced with analytical evaluation if sufficient high-quality test data is available from similar packages to provide high-confidence benchmarking of the models. This position appears to be consistent with the licensing action taken by the NRC on the HOLTEC licensing application for the HI-STAR 190 package, for which physical drop testing was not performed, but licensing of the package was provided on a moderator exclusion basis.

Further the DOE-NR guidance requires demonstration of the effectiveness of the moderation barriers by testing, consistent with Sections 9.4.1.5 and 9.4.2.3 of NUREG-2216 and

Section 680(a) of SSR-6. The Section 2 guidance specifically requires leak rate testing to verify watertight criteria are met during the various phases of package fabrication and operation.

The DOE-NR guidance includes provisions for the development of inelastic strains in components of the moderator barriers. While such strains are undesirable, such strains may be considered acceptable provided that physical testing demonstrates that strains consistent with those predicted in moderator barrier components do not result in a leak rate exceeding the criteria for watertight. This guidance is considered appropriate given the magnitudes of the impact loads involved in accident evaluations of fissile material packages. Further, the guidance provides a clear standard that can be used to assess the acceptability of a design in which some degree of inelastic straining occurs.

As presented herein, the proposed DOE-NR regulatory guidance is consistent with applicable regulatory requirements (10 CFR 71 and IAEA SSR-6), existing regulatory (NUREG-2216 and IAEA SSG-26), and applicable regulatory precedent (Reference (c)).

4 REFERENCES

(a) The Nuclear Waste Policy Act of 1982

(b) NRC Safety Evaluation Report, “Model No. HI-STAR 180 Package”, USNRC Docket No. 71-9325, Revision 1

(c) NRC Safety Evaluation Report, “Model No. HI-STAR 190 Package”, USNRC Docket No. 71-9373, Revision 0

(d) NRC Correspondence, “Summary of April 3, 2007, Telephone Call with HOLTEC International (HOLTEC) to Discuss the Model No. HI-STAR 180 Transportation Package”, Docket No. 71-9325, TAC No. L24070, dated April 11, 2007

(e) NRC Correspondence, “Summary of October 24, 2006, Meeting with HOLTEC International on the HI-STAR 180 Cask”, Docket No. 71-9325, TAC No. L23972, dated October 27, 2006

(f) HOLTEC Report No. HI-2073681, “Safety Analysis Report on the HI-STAR 180 Package”, USNRC Docket No. 71-9325, Revision 7, dated June 21, 2019

(g) NRC Correspondence, “Request for Additional Information for the Review of the Model No. HI-STAR 190 Package”, Docket No. 71-9373, CAC No. L25046, dated April 8, 2016

(h) HOLTEC Report No. HI-2146214, “Safety Analysis Report on the HI-STAR 190 Package”, USNRC Docket No. 71-9373, Revision 3, dated November 2, 2018