

## **UPDATE ON REGULATORY ISSUES ASSOCIATED WITH CRITICALITY SAFETY OF SPENT FUEL CASKS CONSIDERING WATER INLEAKAGE**

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### **ABSTRACT**

Criticality safety requirements in the U.S. specify that a package must be designed and the contents limited so that a single package is subcritical with water in the containment system. Along with this provision, the regulations state that a single package must be subcritical under normal and accident conditions. The regulations allow certain exceptions to these requirements. In May 2003, U.S. Nuclear Regulatory Commission (NRC) staff issued revised technical review guidance regarding the demonstration of subcriticality of a single package under accident conditions. This guidance was issued to address questions regarding the structural integrity of cladding for high burnup fuels, and the possible reconfiguration of the fissile material under accident conditions. For certain cases, the guidance allows the evaluation under accident conditions to be performed without water in the containment system, provided a physical test has demonstrated that the system is water-tight. The guidance specifies that the package must still be shown to be subcritical with water in the containment system with the fuel in the undamaged condition, and considering damage to the packaging. NRC has not approved any spent fuel cask designs that are not subcritical with water in the containment system. However, applicants have indicated that package designs are being developed that may rely on the absence of water for criticality safety. Because of the safety significance of any departure from past practice, the staff is preparing to request Commission guidance regarding this technical issue. This paper will describe recent activities as well as the status of this regulatory issue in the U.S.

### **BACKGROUND**

The NRC approves designs for transportation packages for large (Type B) quantities of radioactive material and fissile material. NRC transportation regulations, including performance standards for these packages, are in 10 CFR Part 71 [1]. Regulations that specify criticality safety requirements for fissile-material packages are 10 CFR 71.55 and 71.59. In certain instances, these provisions specifically address the presence and degree of water moderation that must be assumed when showing subcriticality of the fissile contents under normal conditions of transport and hypothetical-accident conditions. For a single package, 10 CFR 71.55(b) includes the requirement that a package must be designed and the contents limited such that a single

package “would be subcritical if water were to leak into the containment system.” Paragraph 71.55(c) allows the Commission to approve exceptions to this requirement; this is the regulatory basis of moderator exclusion.

The regulations in 10 CFR 71.55 and 71.59 are consistent with, but not identical to, regulations promulgated by the International Atomic Energy Agency (IAEA) [2]. For the purposes of discussion the regulations in 10 CFR 71.55(b) and (c) can be considered analogous to Para. 677 in IAEA TS-R-1. However, there are some differences in the two regulations. One difference is that Para. 677 does not use the term “exception” in reference to designs incorporating moderator exclusion, and gives specific requirements regarding special features that would be needed to allow it. According to Para. 677, special features shall include multiple high standard water barriers that would remain watertight under the regulatory accident conditions. In contrast, 71.55(b) does not specifically invoke the regulatory accident conditions tests, but requires subcriticality considering the most reactive credible configuration of the fissile material. The conditions needed to allow moderator exclusion are also different in 71.55(c). The special design features are not defined except that they must ensure that no single packaging error would permit leakage.

## **DISCUSSION**

Transportation packages are required to be designed and the fissile contents limited, so that the package is subcritical, with fresh water in the containment system. This requirement [codified in 10 CFR 71.55(b)] provides a significant margin of safety and a defense-in-depth against accidental criticality in transport. The requirement that water be assumed within the containment system is not explicitly tied to the ability of the package to limit water in-leakage under the regulatory tests and conditions that simulate normal conditions of transport and accident conditions. Instead, it is a general design requirement that is intended to ensure that no criticality accident could occur in transportation, considering analytical uncertainties and uncertainties in the transportation environment. For spent fuel casks, this requirement also ensures safety during underwater loading and unloading operations.

### **NRC Staff Review Practice to Date**

To date, NRC has not approved any spent fuel transportation package design that could be critical with fresh water in the containment system (i.e., no spent fuel transportation package design has been approved based on moderator exclusion). Practical design methods and features have been used to assure subcriticality of transportation casks for all types of commercial- and research-reactor spent fuel. Such design features include using geometry control and neutron-absorber plates incorporated into the basket structure that supports the fuel elements.

Staff has issued guidance, regarding criticality assessments for transportation package designs for commercial spent fuel, that considers the ability of the cask to prevent water in-leakage under the regulatory hypothetical-accident conditions [10 CFR 71.55(e)]. The guidance was issued by the Division of Spent Fuel Storage and Transportation (SFST), in the Office of Nuclear Material Safety and Safeguards (NMSS), as Interim Staff Guidance No. 19 (ISG-19) [3]. The guidance allows applicants to take credit for moderator exclusion under 10 CFR 71.55(e), provided that physical testing has been used to demonstrate the performance of the water-tight boundary under the regulatory-accident tests. The guidance was developed to address the possibility of fuel reconfiguration to a more reactive geometry under accident conditions, particularly in the case of

high-burnup fuel that has unknown cladding strength and ductility. Although this guidance was issued in 2003, NRC has not yet approved any cask designs using the ISG-19 guidance.

The provisions of 10 CFR 71.55(c) allow the Commission to approve an exception to the requirement that the package must be subcritical with water in the containment system. The staff's long-term practice has been to consider this exception to be appropriate only for limited shipments and not for general approval of a design. Approval of a moderator exclusion exception under 10 CFR 71.55(c) should include risk information appropriate for the conditions of the particular shipments, including consideration of transportation operations, mode, route, and number of shipments. Using the moderator-exclusion provision of 10 CFR 71.55(c) for the general approval of a spent fuel cask design has not been considered appropriate in the past, because it would lead to the routine use of an exception that has important safety implications. In this regard, a Part 71 general design approval would allow an unlimited number of casks to be fabricated to that design, with essentially no restriction on transportation mode, route, or number of shipments.

### **Possible Requests for Approval of Package Designs Based on Moderator Exclusion**

Spent fuel cask designers claim that using moderator exclusion as a basis for package-design approval could result in fewer future spent fuel shipments, since the number of fuel assemblies within a cask could be increased. It is primarily casks designed for an exceptionally large capacity (e.g., 32 pressurized water reactor (PWR) fuel assemblies) or without neutron-absorber plates, that may need to rely upon the moderator exclusion exception of 10 CFR 71.55(c). In those large-capacity casks, using burnup credit in criticality evaluations may provide an alternative method to demonstrate subcriticality even in the presence of fresh water. Burnup credit involves quantifying the decrease in nuclear reactivity of the fuel, from irradiation. The primary difference would be that designs using burnup credit would still incorporate neutron absorbers in the fuel basket. Some cask designers in the U.S. have indicated that they intend to submit applications for package designs that rely on the absence of water to maintain subcriticality. Because any departure from current staff practice would present a change with important safety and policy considerations, the staff intends to request Commission guidance regarding the moderator exclusion issue.

### **Regulatory Options for Moderator Exclusion for Spent Fuel Packages**

In formulating its request for Commission guidance, the staff has identified three possible regulatory options to address the moderator exclusion issue. These options are:

- (1) Retain staff policy to consider moderator exclusion only on a limited-shipment basis, as a 10 CFR 71.55(c) exception to the subcriticality requirement of 10 CFR 71.55(b). Design approvals are not considered appropriate under this regulatory exception. Current staff practice is documented in a number of guidance documents, including standard review plans for transportation package approvals, and other staff guidance. The current staff practice ensures a strong defense-in-depth against accidental criticality in transport. This practice is consistent and in compliance with the regulations in Part 71. Any departure from the current staff practice would need to be considered in the context of additional risk information that quantifies probabilities and consequences of an inadvertent criticality.

- (2) Consider spent fuel cask-design approvals under the provisions of 10 CFR 71.55(c), with additional risk information. Although staff practice has been consistent in that no package designs have been approved based on moderator exclusion, there is ambiguity in the regulations in 71.55(b) and (c). Although the spent fuel casks are robust structures, and the transportation system is safe, NRC has not previously approved designs for spent fuel packages under the provisions of 71.55(c). The staff has indicated that significant risk information would be needed to approve a package design on that basis. This risk information would be needed to supplement the package evaluation to the performance requirements in Part 71.
- (3) Initiate rulemaking to codify the possible use of moderator exclusion for spent fuel transportation packages. Rulemaking appears to be the most appropriate pathway to resolve technical and policy issues associated with moderator exclusion. The staff believes that a risk-informed regulation specifically addressing moderator exclusion in certain spent fuel packages and under certain conditions could be developed. The regulation could clarify the requirements of 10 CFR 71.55, and provide specific requirements for design approval using moderator exclusion. The rulemaking process also provides an opportunity for public and other stakeholder involvement in addressing any change in staff practice and policy that has important safety implications.

## **RECENT ACTIVITIES AND STATUS**

### **Advisory Committee on Nuclear Waste and Materials Presentation and Recommendations**

In anticipation of requesting direction directly from the Commission, the staff presented a technical briefing for the Advisory Committee on Nuclear Waste and Materials (ACNW&M). The ACNW&M is independent from the NRC staff, and acts as an expert advisor to the Commission. The ACNW&M reports to and advises the Commission on all aspects of nuclear waste management, including activities related to the transportation, storage, and disposal of high-level and low-level radioactive waste, the interim storage of spent nuclear fuel; materials safety; decommissioning; and related issues. The ACNW&M also requested presentations on moderator exclusion from other stakeholders that had an interest in pursuing package designs using it as a basis for criticality safety. Based on these presentations, round-table discussions, and other information, the ACNW&M provided written recommendations to the Commission regarding the moderator exclusion issue. The ACNW&M recommended that the staff use the existing rule in 10 CFR 71.55(c) to evaluate submittals from applicants seeking to apply moderator exclusion provisions. The Committee also recommended that a decision regarding future rulemaking should be deferred until more experience is gained using the existing provisions. The ACNW&M also noted that the moderator exclusion and burnup credit issues are not separate issues, in that either or both would allow a large quantity of spent fuel to be transported in a single package. The ACNW&M recommended that guidance be made risk-informed and include consideration of both moderator exclusion and burnup credit.

### **Current Status**

The staff is preparing a paper that requests Commission direction concerning the moderator exclusion issue.

## REFERENCES

- [1] United States Code of Federal Regulations, Title 10, Part 71, “Packaging and Transportation of Radioactive Material.”
- [2] International Atomic Energy Agency Safety Standards, Safety Requirements No. TS-R-1, “Regulations for the Safe Transport of Radioactive Material,” 2005 Edition.
- [3] U.S. Nuclear Regulatory Commission, Division of Spent Fuel Storage and Transportation, Office of Nuclear Material Safety and Safeguards, Staff Interim Guidance Document No. 19, “Moderator Exclusion under Hypothetical Accident Conditions and Demonstrating Subcriticality of Spent Fuel under the Requirements of 10 CFR 71.55(e),” Rev. 0, May 2003.