Request for Comment on

Retrievability, Cladding Integrity and Safe Handling of Spent Fuel at an Independent Spent Fuel Storage Installation and During Transportation

I. Introduction

Regulations for packaging and transport of spent nuclear fuel are set forth in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 71, while requirements for storage of spent nuclear fuel are set forth in 10 CFR Part 72. Because these regulatory schemes are separate, there is no requirement that licensed and loaded storage casks also meet the transportation requirements in 10 CFR Part 71. Integration of storage and transport regulations could enable a more predictable transition from storage to transport by potentially minimizing future handling of spent fuel and uncertainty as to whether loaded storage casks may be transported from the storage location. As part of its evaluation of integration and compatibility between storage and transportation regulations, the U.S. Nuclear Regulatory Commission (NRC) staff is reviewing its policies, regulations, guidance, and technical needs on retrievability, cladding integrity, and safe handling of spent fuel. NRC is soliciting external stakeholder feedback on (1) its retrievability and cladding integrity policy and regulations for spent fuel storage and (2) whether similar regulations and policies should be implemented for spent fuel transportation. The NRC is seeking comments on questions set forth in Section VI.

II. Background

A. Retrievability Requirements

Section 141(b)(1)(C) of the Nuclear Waste Policy Act (NWPA), requires that each monitored retrievable storage (MRS) facility be designed "to provide for the ready retrieval of such spent fuel and waste for further processing or disposal." The NRC codified this portion of the NWPA in its 1988 final rulemaking "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste" (53 FR 31651; August 19, 1988) to require that "Storage systems must be designed to allow ready retrieval of spent fuel or high-level radioactive waste for further processing or disposal," in 10 CFR 72.122(l) and added MRSs to the scope of 10 CFR part 72. This requirement currently applies to all independent spent fuel storage facilities (ISFSIs) and MRS licensees.

B. Spent Fuel Storage Cladding Integrity Requirements

In the 1980 final rulemaking adding 10 CFR part 72, ''Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Fuel Storage Installation" (45 FR 74693; November 12, 1980) to its regulations, the NRC required that, for all specific licensed ISFSIs, the fuel cladding be protected against degradation and gross ruptures. The NRC further clarified this regulation in the 1988 final rulemaking that added MRSs in the scope of 10 CFR part 72. The NRC requires in 10 CFR 72.122(h)(1) that "The spent fuel cladding must be protected during storage against degradation that leads to gross ruptures or the fuel must be otherwise confined such that degradation of the fuel during storage will not pose operational safety problems with respect to its removal from storage. This may be accomplished by canning of consolidated fuel rods or unconsolidated assemblies or other means as appropriate." (53 FR at 31673) This requirement applies to all ISFSI and MRS licensees.

C. Spent Fuel Transport Requirements for Geometry of Contents

In the July 22, 1966, final rulemaking "Part 71 - Packaging of Radioactive Material for Transport" (31 FR 9941, 9946) that revised 10 CFR part 71 to add performance standards that packages need to meet for approval, the NRC revised the requirements in 10 CFR 71.35, "Standards for Normal Conditions of Transport for a Single Package," to require that "(b) A package used for the shipment of fissile material shall be so designed and constructed and its contents so limited that under the normal conditions of transport specified in Appendix A of this part: (1) The package will be subcritical; (2) The geometric form of the package contents would not be substantially altered." 31 FR at 9946. In the 1983 rulemaking "Rule to Achieve Compatibility With the Transport Regulations of the International Atomic Energy Agency (IAEA)" (48 FR 35600; August 5, 1983), these regulations originally located at 10 CFR 71.35 were renumbered to 10 CFR 71.55(d)(1) and 10 CFR 71.55(d)(2), its current location in the regulations.

III. Historical Regulatory Interpretations of Retrievability and Cladding Integrity

Over the past 30 years, NRC has predominantly licensed and certified low burnup fuel for storage and transportation. In 1998, the NRC staff issued Interim Staff Guidance No. 1 (ISG-1), "Damaged Fuel" (ADAMS Accession No. ML090850129) and ISG-2, "Fuel Retrievability" (ADAMS Accession No. ML092800367). ISG-1 defined damaged fuel and stated that it should be individually canned for both storage and transportation to confine gross particulates and maintain a subcritical geometry. ISG-2 provided guidance to the NRC staff on a method to determine whether the design of a storage system allows for ready retrieval of spent fuel. In ISG-2, the NRC staff stated that compliance with retrievability requirements in 10 CFR 72.122(l) is achieved when an ISFSI allows for decommissioning (i.e., storage system design has the capability to be placed into a transportation package for off-site shipment) and has limited license terms.

Subsequent to the NRC staff issuing ISG-1 and ISG-2, the NRC issued an information paper to the Commission, SECY-01-0076, "Retrievability of Spent Fuel from Dry Storage Casks," (ADAMS Accession No. ML011020520) to inform the Commission of the NRC staff position on retrievability. The NRC staff stated that it considered fuel assemblies to meet the retrievability requirements in 10 CFR part 72 if the fuel assemblies remained structurally intact during the storage period for normal and off-normal events. Spent fuel assemblies would be considered structurally intact if the fuel assemblies could be handled by normal means. In this paper, the NRC staff informed the Commission that it would maintain the position that retrievability requires that each individual assembly or canned assembly be retrievable, and alert the Commission if another definition of retrievability became a viable option. To date, the NRC staff has not provided the Commission with a different definition of retrievability.

The NRC staff revised ISG-1 in 2002 (ADAMS Accession No. ML022980322) and 2007 (ADAMS Accession No. ML071420268) and renamed it "Classifying the Condition of Spent Nuclear Fuel for Interim Storage and Transportation Based on Function." The NRC staff recognized that the definition of damaged fuel had evolved over the course of storage cask and transportation package reviews. The NRC staff recognized that there were other fuel assembly defects that would designate the fuel assembly as damaged, when in fact, the cladding may not be breached, and the fuel could be handled by normal means. In the revised guidance, the NRC staff expanded the definition of damaged spent fuel (beyond cladding defects greater than hairline cracks or pinhole leaks) to address degraded fuel conditions (such as missing grid spacers) and recognized that low burnup fuel assemblies without gross cladding defects could still be considered retrievable, since they should not undergo further damage in storage or transportation. In the latest revision, the NRC staff refined the damaged fuel evaluation and included consideration of whether the spent fuel will be transported or stored, since the regulatory requirements for the spent fuel are different in each case.

In 2010, the NRC staff issued ISG-2, Revision 1 (ADAMS Accession No. ML100550861), which stated that the NRC staff considers spent fuel in storage to be retrievable when both the canister can be removed from the storage cask and each fuel assembly can be removed from the storage canister (or cask if a bolted closure with no canister) for repackaging for either continued storage (in the event the need arises) or transportation. The NRC staff defined a spent fuel assembly to be retrievable if it remains structurally sound and can be handled by normal means or is canned, consistent with the definitions of damaged and undamaged spent fuel in ISG-1.

The NRC concluded that spent fuel that remains undamaged during storage meets the retrievability requirements in 10 CFR part 72. As such, applicants for an ISFSI license or storage cask certificate of compliance typically show that licensees will meet these requirements by evaluating undamaged fuel assemblies and showing that these assemblies will not degrade during the allowed storage term. The storage cask is evaluated for normal and off-normal conditions of storage to ensure that the fuel assemblies remain in an inert environment are not mechanically damaged, and the cladding temperatures remain below the maximum temperatures determined to limit fuel degradation.

IV. Current Spent Fuel Storage Cladding Integrity Technical Issues

The spent fuel cladding is the first barrier against release of radioactive material and maintains geometry control for criticality safety during dry cask storage and transportation. The spent fuel cladding is not the primary barrier relied on to provide containment for spent fuel transportation packages or confinement for dry storage casks. Rather, spent fuel transportation packages have a defined containment boundary that typically consists of a welded shell with a bolted lid, which are leak testable to ensure that the package is fabricated in accordance with the approved design that was shown to meet the containment criteria in 10 CFR part 71. Similarly, spent fuel storage casks have a defined confinement boundary that consists of either a welded canister or a welded shell with a bolted lid, which is similar to a transportation package design. The confinement boundary for dry storage casks is also leak tested to ensure that the confinement boundary was fabricated in accordance with the approved design.

NUREG-1092, “Environmental Assessment for 10 CFR Part 72 Licensing Requirements for the Independent Storage of Spent Fuel and High-Level Radioactive Waste,” (ADAMS Accession No. ML091050510) was prepared for the proposed rulemaking “Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste” (51 FR 19106; May 27, 1986) and subsequent 1988 final rulemaking that added the retrievability and cladding integrity requirements in 10 CFR part 72. Part of this rulemaking revised the requirements to ensure that spent fuel cladding is protected from gross defects and stated the cladding need not be maintained if additional confinement is provided. The evaluation in NUREG-1092 determined that the primary reason to maintain cladding integrity is to reduce the potential exposure to radioactive material during the handling operations when removing the spent fuel from storage and transferring it to packages for shipment. Finally, NUREG-1092 stated that the potential exposure could be prevented by confining the spent fuel, since this confinement could act as a replacement for the cladding, reducing potential exposure to the radioactive material. NRC has accepted damaged fuel cans for individual fuel assemblies as a method acceptable to meet the requirement to provide additional confinement.

The “License and Certificate of Compliance Terms” final rulemaking (76 FR 8872; February 16, 2011), extending the term of an ISFSI license and storage cask certificate of compliance to 40 years, noted that the NRC staff expects very little to no degradation of low burnup spent fuel at the end of the 40-year storage period. This was based partly on a joint NRC, Electric Power Research Institute (EPRI), and the Department of Energy (DOE) program that opened a storage cask containing low burnup fuel at the Idaho National Laboratory after 15 years of storage and found no degradation of low burnup fuel (NUREG-CR/6831, “Examination of Spent PWR Fuel Rods After 15 Years in Dry Storage,” ADAMS Accession No. ML032731021).

For high burnup fuel assemblies(fuel with peak rod average burnup greater than 45,000 MWd/MTU is considered high burnup fuel), little data are currently available to confirm that these fuel assemblies would retain their structural integrity during storage periods longer than 20 years. If applicants are unable to demonstrate that the fuel assemblies can be handled using normal means and that fuel cladding will not significantly degrade during storage periods longer than 20 years, then verification of the cladding integrity may be needed. If subsequent data are obtained that contradicts the current licensing assumptions on spent fuel integrity, it may be necessary to repackage the fuel and place it into individual cans to meet retrievability requirements, using the current definition of retrievability.

Although there is a lack of data on the material properties (such as ductility) of high burnup fuel cladding, recent testing has indicated that, depending on the storage conditions, the ductile-to-brittle-transition temperature of specific types of high burnup cladding may have increased substantially due to hydride reorientation. The ductile-to-brittle-transition temperature controls when the spent fuel cladding will transition from being a ductile material to a brittle material. As the fuel remains in storage, its temperature will drop due to radioactive decay. If the fuel’s temperature, at the time of transport, is below the ductile-to-brittle-transition temperature, the chances for damage to the fuel cladding under normal shipping conditions will increase.

If consolidated interim storage of spent fuel were to become operational, consistent with the Blue Ribbon Commission on America’s Nuclear Future January 2012 report, a large-scale transportation program would begin. The spent fuel would be transported at least twice to get it to a repository − once from the reactor to the consolidated storage facility and then to the repository − after an unknown storage duration. Given the uncertainty in material properties of high burnup fuel, it is not clear if multiple transports would have a negative impact on spent fuel integrity and its suitability to meet the regulations for a second storage period after transport.

Currently loaded storage casks are not designed for in-situ monitoring to determine the condition of the spent fuel during storage. Neither sealed canister designs (the majority of currently loaded storage systems) nor integral dual-purpose casks allow for internal examination of the fuel without opening the system. Changes in spent fuel integrity and cladding material properties during storage can only be evaluated through an experimental program, such as a dedicated demonstration project, laboratory testing or bringing a loaded cask back into the pool to be reopened for fuel examination.

The NRC staff has been seeking additional information on the material properties of the high burnup fuel and its ability to meet storage and transportation regulatory requirements for current licensing and certification activities. The NRC evaluation of high burnup fuel properties includes: evaluating the range of technical considerations; monitoring any related demonstration programs; development of regulatory considerations for extended storage and transportation, along with recommendations for risk-informing and streamlining the storage and transportation regulatory process; assessing aging management plans; and developing the basis to minimize or avoid unnecessary opening and repackaging of the spent fuel. NRC is also testing high burnup fuel to determine if current issues exist regarding the effects of hydride reorientation, which might occur during drying, on the expected ductility of the cladding during storage and transportation and to evaluate the fatigue response of high burnup fuel under normal transportation conditions.

V. Retrievability Options

The NRC is assessing the current regulations and policy on retrievability to determine whether to maintain the current definition of retrievability or move towards canister-based retrievability. Both of these options have benefits and challenges that will need to be addressed in licensing and certification actions.

A. Fuel Assembly-Based Retrievability

As discussed above, existing NRC policy is that each individual fuel assembly should be retrievable from storage.

Benefits of this assembly-based retrievability approach are that it provides defense-in-depth against releases through cladding integrity or canning of individual fuel assemblies and is the most straightforward means of ensuring safe handling of the spent fuel for further processing or disposal.

Challenges of assembly-based retrievability include: (1) the lack of reliable data for fuel cladding subjected to high burnups and extended storage periods, or the need to extrapolate licensing parameters from limited existing data points; (2) the overall inability to reliably monitor fuel cladding conditions during storage; and (3) cladding degradation may not be preventable over long timeframes and each storage licensee would bear the potential costs of repackaging loaded spent fuel into individual fuel cans to maintain retrievability, if the fuel cladding degrades sufficiently to cause gross ruptures during storage.

B. Canister-Based Retrievability

Some stakeholders have recommended, and NRC is evaluating, revising the regulatory framework to move towards a policy of canister-based retrievability. Canister-based retrievability would allow fuel cladding degradation without further confinement measures inside welded canisters. The technical basis underpinning the storage application would assume that fuel degradation could occur and account for fuel degradation and any credible fuel reconfiguration in the confinement, shielding, and criticality evaluations to ensure safety. In this approach, the spent fuel would not have to be repackaged during storage due to changes in the fuel cladding condition. Repackaging would be needed only if the canister fails and requires replacement.

The potential benefits of this approach are that: (1) the condition of the canister may be easier to demonstrate and monitor than the condition of the fuel cladding; (2) canning of individual fuel assemblies, fuel inspection, and repackaging by storage licensees would be minimized; and (3) repackaging would likely only be required if a canister failed and could not be repaired.

The potential challenges of the canister-based retrievability are that, if the spent fuel were to degrade during storage, the defense-in-depth provided by the cladding (as the first line of defense against release of radioactive material) would be compromised. An additional challenge would arise if the DOE does not accept canisters loaded prior to developing canister acceptance criteria for disposal in a repository. Spent fuel with unknown physical properties would need to be individually handled and repackaged for disposal. Repackaging could be done at a storage facility or by the DOE at the repository. This may result in the need to handle an unknown but potentially significant quantity of weakened or damaged spent fuel that is not in individual fuel assembly cans. This could strongly affect the design of a potential geologic repository, as well as the type and capacity of surface handling facilities at the disposal site. Spent fuel degradation during storage may also impact both handling and fuel assay knowledge for use in a reprocessing facility, if the U.S. were to move to reprocess some spent fuel.

VI. Request for Public Comment

The objective of this document is to solicit external stakeholder input as the NRC reviews its policies, regulations, guidance, and technical needs in the area of retrievability, cladding integrity and safe handling of spent fuel. The sections below include questions that are intended to solicit comments that will assist the NRC staff in evaluating the appropriate definition of retrievability for storage, whether cladding integrity regulations should be maintained or revised, and whether retrievability, and what definition of retrievability, should be extended to transportation of spent fuel.

A. Acceptance of Spent Fuel by a Future Disposal or Reprocessing Facility

Given the state of knowledge and expertise in both national and international programs for disposal of spent fuel, and the fact that industry is loading and maximizing dual-purpose cask capacities to minimize cask fabrication and operational costs, including increasing fissile capacity and thermal heat, it is possible that much (if not all) of the spent fuel currently being loaded and stored will need to be repackaged prior to disposal. Current mined geologic repository designs utilize disposal packages with smaller thermal, weight, and fissile material capacities. Additionally, specific storage canister material requirements/prohibitions may be needed to meet performance requirements of a repository, which are driven by the design and site characteristics of the repository, and not canister handling needs. A canister-based retrievability framework may place significant additional siting and design constraints on the operator of a future geologic disposal facility.

Current reprocessing technology typically utilizes undamaged fuel to reduce contamination when unloading transportation packages and to ensure accurate knowledge of the spent fuel characteristics. Reprocessing spent fuel that had degraded during storage may increase the size of the hot cell facility needed to unload the spent fuel transportation package or may result in a larger portion of the facility being contaminated. Additionally, significant spent fuel degradation during storage may make it more difficult to ensure accurate knowledge of spent fuel pieces used as input to a reprocessing facility.

The NRC would like external stakeholders to respond to the following questions regarding potential repackaging needs for storage casks that will be loaded and placed in storage prior to development of a repository or reprocessing facility.

1. Should an enhanced regulatory framework assume the licensee receiving spent fuel for disposal will be able to site and design a repository for direct disposal of these high-capacity canisters without repackaging?

2. Should an enhanced regulatory framework assume the repository licensee will be able to handle and repackage potentially degraded/damaged fuel on large production scales?

3. What effects, if any, would a canister-based retrievability policy have on a future reprocessing facility?

4. What other factors, such as cost, dose or time, should be considered?

B. Spent Fuel Retrievability During Storage

Given the uncertainty with the material properties of high burnup spent fuel, it is unclear whether some spent fuel may degrade during storage periods longer than 20 years and subsequent transportation. The NRC would like external stakeholders to provide an assessment of (1) whether ready-retrieval of individual spent fuel assemblies during storage should be maintained, or (2) whether retrievability should be canister-based. External stakeholders are encouraged to provide as much explanatory information as is available and pertinent for the Commission to consider when evaluating whether to revise its retrievability policy.

C. Cladding Integrity

The current regulatory practice is to ensure fuel assembly retrievability by showing that there will not be significant spent fuel degradation during storage so that the assemblies can be handled by normal means. Until such time that sufficient material properties of high burnup fuel are obtained, storage applicants and licensees may not be able to show that there will not be any gross degradation of the fuel during renewed storage license terms or license and certificate terms greater than 20 years. This may mean that in order to ensure retrievability, all high burnup fuel assemblies should be canned prior to dry storage or cask designs and storage programs should be developed to allow direct inspection of the spent fuel condition during storage in casks on a periodic basis. Additionally, if current research programs on high burnup fuel material properties were to show that the cladding will degrade significantly during storage, currently loaded fuel assemblies may need to be repackaged. The NRC would like external stakeholders to respond to the following questions to support the NRC's efforts to determine whether the policies and regulations on spent fuel cladding should be revised.

1. Should the spent fuel cladding continue to be protected from degradation that leads to gross rupture, or otherwise confine the spent fuel, during storage such that it will not pose operational safety problems with respect to its removal from storage? In particular, provide any explanatory information discussing the additional cost, dose, and effort required to repackage potentially damaged fuel over canned spent fuel, if the prohibition against gross deformation to the cladding were removed and the spent fuel required repackaging (whether by DOE or storage licensees).

2. Should each high burnup spent fuel assembly be canned to ensure individual fuel assembly retrievability? Additionally, should spent fuel assemblies classified as damaged prior to loading continue to be individually canned prior to placement in a storage cask? In particular, NRC is interested in gathering input on the additional cost, dose, and effort required to place individual fuel assemblies in a damaged fuel can during storage cask loading. Comparison of the upfront cost, dose, and effort to can all high burnup fuel assemblies against the cost, dose, and effort to repackage potentially damaged fuel at a repository or prior to transport to a repository, may factor into NRC's retrievability policy decisionmaking process.

D. Transportation Retrievability

Unlike the ISFSI storage regulations in 10 CFR part 72, the transportation regulations in 10 CFR part 71 do not have an explicit regulatory requirement for spent fuel to be retrievable after normal conditions of transport (i.e., able to be unloaded after transport using normal means). Instead, the transport regulations at 10 CFR 71.89 (60 FR 50264, 50278, September 28, 1995) contain the requirement that any special instructions needed to safely open the package have been provided to the consignee for its use in accordance with 10 CFR 20.1906(e) (56 FR 23403, May 21, 1991). The NRC considers that any procedures necessary to safely unload the package are part of the opening instructions.

1. The NRC would like external stakeholders to comment on (a) whether retrievability should be extended to transportation packages after normal conditions of transportation (similar to the storage requirements), or (b) is it acceptable for high burnup spent fuel to degrade such that damaged fuel may have to be handled when the package is opened? Extending retrievability to transportation may be important if the U.S. were to move to consolidated interim storage, and if the NRC were to maintain its current definition of assembly-based retrievability during storage.

2. If it is acceptable for the fuel to degrade, should the package application for a certificate of compliance provide a description of the design and operations of any facilities and methods necessary to handle the damaged fuel (at the facility that will open the package)?

VII. Availability of Supporting Documents

The following documents provide additional background and supporting information regarding this request for comment. The documents can be found using any of the methods provided in the table. Instructions for accessing ADAMS were provided under the SUPPLEMENTARY INFORMATION section of the *Federal Register* Notice. The Federal Register Notice can also be found in ADAMS using Accession No. ML12293A430.

Date	Document	ADAMS Accession No./Web link/Federal Register citation
January 7, 1983	Nuclear Waste Policy Act of 1982	Accessible from the U.S. Senate at http://epw.senate.gov/nwpa82.pdf
August 19, 1988........	Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste	53 FR 31651
November 12, 1980	Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Fuel Storage Installation	45 FR 74693
July 22, 1966.............	Part 71 - Packaging of Radioactive Material for Transport	31 FR 9941
August 5, 1983..........	Rule To Achieve Compatibility With the Transport Regulations of the International Atomic Energy Agency (IAEA)	48 FR 35600

November 2, 1998	Interim Staff Guidance No. 1, "Damaged Fuel"	ML090850129
October 6, 1998	Interim Staff Guidance No. 2, "Fuel Retrievability"	ML092800367
April 26, 2001	SECY-01-0076, "Retrievability of Spent Fuel from Dry Storage Casks"	ML011020520
October 25, 2002	Interim Staff Guidance No. 1, Revision 1, "Damaged Fuel"	ML022980322
May 11, 2007	Interim Staff Guidance No. 1, Revision 2, "Classifying the Condition of Spent Nuclear Fuel for Interim Storage and Transportation Based on Function"	ML071420268
February 22, 2010.....	Interim Staff Guidance No. 2, Revision 1, "Fuel Retrievability"	ML100550861
August 31, 1984........	NUREG-1092, "Environmental Assessment for 10 CFR Part 72 'Licensing Requirements for the Independent Storage of Spent Fuel and High-Level Radioactive Waste' "	ML091050510
May 27, 1986	Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste	51 FR 19106
February 16, 2011.....	License and Certificate of Compliance Terms	76 FR 8872
September 30, 2003 .	NUREG-CR/6831, "Examination of Spent PWR Fuel Rods after 15 Years in Dry Storage"	ML032731021
January 26, 2012	January 2012 report, the Blue Ribbon Commission on America's Nuclear Future	Accessible from Blue Ribbon Commission on America's Nuclear Future archives at http://cybercemetery.unt.edu/archive/brc/20120620220235/http://brc.gov/sites/default/files/documents/brc_finalreport_jan2012.pdf
January 26, 2004	Compatibility With the International Atomic Energy Agency (IAEA)	60 FR 50264, 50278
May 21, 1991	Standards for Protection Against Radiation	56 FR 23360, 23403