Division of Spent Fuel Storage and Transportation
Interim Staff Guidance-24, Revision 0

Issue: The Use of a Demonstration Program as Confirmation of Integrity for Continued Storage of High Burnup Fuel Beyond 20 Years

Title 10 of the *Code of Federal Regulations* (10 CFR) Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste," requires that storage of the waste meet various criteria. One criterion requires the spent fuel cladding be protected during storage against degradation that leads to gross ruptures, or not pose operational safety problems with respect to its removal from storage. (see 10 CFR 72.122(h)(1)). Additionally, storage systems must be designed to allow ready retrieval of the waste for further processing or disposal. (see 10 CFR 72.122(l).

This Interim Staff Guidance (ISG) document provides guidance to the staff for reviewing if a demonstration of high burnup fuel (HBF) has the necessary properties to qualify as one method that an applicant might use in license and certificate of compliance (CoC) applications to demonstrate compliance with 10 CFR 72.122(h)(1) and 10 CFR 72.122(l). This guidance is not a regulatory requirement. Alternative approaches may be used to demonstrate safety and compliance, as appropriately justified by an applicant.

Discussion:

The experimental confirmatory basis that low burnup fuel (≤45 GWd/MTU) will maintain its integrity in dry cask storage over extended time periods was provided in NUREG/CR-6745 (Ref. 1), "Dry Cask Storage Characterization Project—Phase 1; CASTOR V/21 Cask Opening and Examination" and NUREG/CR-6831 (Ref. 2), "Examination of Spent PWR Fuel Rods after 15 Years in Dry Storage."

A confirmatory basis, which includes information over a similar length of the time available for low burnup fuel, does not exists for HBF (>45 GWd/MTU). Certification and licensing HBF for storage was permitted for an initial 20-year-term using the guidance contained in ISG-11, Rev. 3, (Ref. 3) which was based on short term laboratory tests and analysis that may not be applicable to the storage of HBF beyond 20 years, particularly with the current state of knowledge regarding HBF cladding properties. (Ref. 4)

One concern stated in ISG-11, Rev. 3, was the potential detrimental effects, such as reduced ductility, of hydride reorientation on cladding behavior. Research performed in Japan and the United States indicated that: 1) hydrides could reorient at a significantly lower stress than previously believed, and 2) HBF could exhibit a ductile-to-brittle transition temperature (DBTT) due to the presence of radial hydrides. (Ref. 4) This phenomenon could influence the retrievability of HBF assemblies and result in operational safety problems as HBF cooled. Circumferential zirconium hydrides in the fuel cladding regions would dissolve into the fuel cladding during drying and precipitate (reorient) as radial hydrides as the fuel cladding cooled. Thus, fuel cladding with radial hydrides that is below a DBTT could be too brittle to retrieve on an assembly basis. The maximum temperatures and internal rod pressures, in ISG-11, Rev. 3, were recommended to mitigate hydride reorientation and are applicable to HBF during the initial 20-year storage, as the decay heat of HBF is expected to maintain cladding temperatures above a DBTT (~ 200^{o}C).

While there is no evidence to suggest that HBF cannot be safely stored beyond 20 years, data supporting readily retrievable storage of HBF beyond 20 years is not presently available for the time periods used to support retrievability and storage of low burnup fuel. Therefore, confirmatory data or a commitment to obtain data on HBF and taking appropriate steps in an aging management plan (AMP) will provide further information that will be useful in evaluating the retrievability and storage of HBF for more than 20 years.

A demonstration program could provide an acceptable method for an applicant to demonstrate compliance with the cited regulations for storage of HBF for periods of greater than 20 years by:

1. Confirming the expected fuel conditions, based on technical arguments made in ISG-11, Rev. 3, after a substantial storage period (~ 10 years). The behavior of the cladding for the renewal term will depend on its physical condition at the end of the initial 20 year storage period.
2. Providing data for benchmarking, confirming predictive models and updating aging management plans.
3. Justifying the basis for time-limited aging analyses (TLAA). While regulations call for TLAA and an AMP, since an AMP is currently very difficult to implement in a sealed system, data to justify TLAA is imperative.
4. Identifying any aging effects that may be missed through short-term accelerated studies and analyses.

Monitoring of the fuel temperatures and conditions in the cask combined with physical examination of the fuel at periodic intervals should be able to provide confirmation that:

1. The models of the phenomena used for the first 20-year predictions can be used for the TLAA beyond 20 years.
2. The condition of the fuel after 20 years of storage.
3. New degradation mechanisms are not operating.

Extrapolation outside the recorded data carries risk, but that risk can be minimized if the length of the extrapolation is reduced and those extrapolations are updated as the demonstration continues to monitor and measure fuel properties.

Regulatory Basis:

- 10 CFR 72.122(h)(1) 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.

- 10 CFR 72.122(l) *Retrievability*. Storage systems must be designed to allow ready retrieval of spent fuel, high-level radioactive waste, and reactor-related greater than Class C waste for further processing or disposal.

Applicability:

This guidance applies to license and CoC applications for the storage of HBF for periods greater than 20 years. This guidance supplements the guidance given in NUREG-1927 on aging management for the interior of the cask. (Ref. 5)

Technical Review Guidance:

The applicant may use the results of a completed demonstration or an on-going demonstration if the conditions of the demonstration meet the requirements stated below for the fuels and conditions of storage for which the term is to be renewed. A description of the demonstration, as described in the Safety Analysis Report, shall be incorporated as an enforceable condition that is placed in the CoC. In either case, the demonstration must be in conjunction with an actively updated AMP as an acceptable means for confirming that the canister or cask contents satisfy the applicable regulations. Since limited AMP action can be taken inside a sealed canister, the AMP must ensure that the TLAA is updated with new information as it becomes available, and if the revised TLAA indicates a problem, a plan of action would be developed for mitigation depending on the type and severity of conditions expected.

The following general requirements should be included for a demonstration program for storage of HBF beyond 20 years to be applicable to support a license or certificate application:

1. The maximum burnup of the fuel intended as content in a license application shall be no more than four GWd/MTU greater than the burnup of the fuel used in the demonstration program and shall be of the same cladding type. The demonstration program may have to expand as burnups increase and new fuel claddings are introduced.

2. The demonstration canister will be dried by a widely recognized industry method that results in peak cladding temperatures which bound the peak cladding temperatures requested in the license application. The thermal models used to license the renewal must use the input data from the demonstration to show that the temperatures in the demonstration are bounding.

3. The interior of a helium-filled demonstration canister will be monitored continuously for moisture, hydrogen, oxygen, fission gas, and fuel cladding axial temperature distribution.

4. As a minimum, physical examination of stored rods at periodic intervals to determine cladding creep, fission gas release, hydride reorientation, cladding oxidation and mechanical properties.

5. The demonstration program fuel shall include at least two full fuel assemblies. The assemblies may be reconstituted.

6. Data from the demonstration program must be indicative of a storage duration long enough to justify extrapolation to the total storage time requested but no less than 10 years if the data is to be used to support license extension from 20 – 40 years. The evaluation of the data from the monitoring and examination of individual rods shall be available prior to the end of the currently approved storage period.

An actively updated AMP should be periodically re-evaluated given the current state of knowledge regarding the ability of HBF to meet the regulatory requirements while in dry cask storage. Licensing conditions should require updated AMPs to be submitted to the NRC whenever new data from the demonstration or other short-term tests or modeling indicates potential degradation of the fuel or deviation from the assumptions of the TLAA or AMP. Updates to TLAAs and AMPs will be subject to inspection.

Recommendations:

The staff recommends that NUREG-1927 (Ref. 5) be modified to add this guidance in Section 3.4.3 Aging Management Activity.

Approved: ____________**[DRAFT]**____________ ____________________

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Date

References:

[1] NUREG/CR-6745, "Dry Cask Storage Characterization Project-Phase 1: CASTOR V/21 Cask Opening and Examination." Idaho National Engineering & Environmental Lab, September, 2001.

[2] NUREG/CR-6831, "Examination of Spent PWR Fuel Rods after 15 Years in Dry Storage." Argonne National Laboratory, September 2003.

[3] Interim Staff Guidance - 11, Revision 3, "Cladding Considerations for the Transportation and Storage of Spent Fuel." U.S. Nuclear Regulatory Commission, November 2003.

[4] M.C. Billone, T.A. Burtseva, and R.E. Einziger, "Ductile-to-Brittle Transition Temperature for High-Burnup Cladding Alloys Exposed to Simulated Drying-Storage Conditions," in the Journal of Nuclear Materials Volume 433, Issues 1–3, pages 431–448, February 2013.

[5] NUREG-1927, "Standard Review Plan for Renewal of Spent Fuel Dry Cask Storage System Licenses and Certificates of Compliance Final Report." U.S. Nuclear Regulatory Commission, March 2011.