

UNITED STATES  
NUCLEAR REGULATORY COMMISSION  
OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS  
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**NRC DRAFT REGULATORY ISSUE SUMMARY 2015-XX  
CONSIDERATIONS IN LICENSING<sup>1</sup> HIGH BURNUP SPENT FUEL IN  
DRY STORAGE AND TRANSPORTATION**

**ADDRESSEES**

All applicants for, a: (1) spent fuel transportation package certificate of compliance (CoC) under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 71, "Packaging and Transportation of Radioactive Material"; (2) spent fuel storage CoC under 10 CFR Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste, and Reactor-Related Greater than Class C Waste"; and (3) 10 CFR Part 72 specific license for an independent spent fuel storage installation (ISFSI). This RIS is also being provided, for information, to all holders of a transportation CoC under 10 CFR Part 71; a spent fuel storage CoC under 10 CFR Part 72; specifically licensed ISFSIs under 10 CFR Part 72; 10 CFR Part 72 general licensees; as well as all Agreement and non-Agreement States and State Liaison Officers.

**INTENT**

The U.S. Nuclear Regulatory Commission (NRC) is issuing this regulatory issue summary (RIS) to provide information on some approaches acceptable to the NRC for demonstrating compliance with regulations in applications for issuance of dry storage cask CoCs, ISFSI licenses, and CoCs for transportation packages involving high burnup spent fuel (HBF).

No specific action or written response is required. The NRC is providing this RIS for information only.

**BACKGROUND**

The NRC staff (staff) has relied on results from the Idaho cask demonstration (See NRC's Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML013020363 and ML032731021) and the NRC's Interim Staff Guidance (ISG) - 11, Revision 3, "Cladding Considerations for the Transportation and Storage of Spent Fuel," (ADAMS Accession No. ML033230335) to license the storage and transportation of low burnup spent fuel (LBF) for both an initial license term as well as for renewal terms.

The staff has also relied on guidance provided in ISG - 11, Revision 3, to review the expected behavior of HBF (assembly average burnup exceeding 45 gigawatt days per metric ton of uranium (GWd/MTU)) for up to 20 years in dry storage in the same manner as LBF. While the staff believes that the performance of HBF should be satisfactory, data for HBF similar to that

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<sup>1</sup> Throughout this RIS, the term "licensing" refers to both the issuance of specific licenses for storage of spent fuel and the issuance of certificates of compliance for dry cask storage systems and spent fuel transportation packages.

obtained for LBF through the Idaho demonstration cask will confirm HBF cladding behavior for both the initial 20 year dry storage licensing term and beyond. This data would confirm the cladding creep behavior and the reorientation of precipitated cladding hydrides resulting from vacuum drying and dry storage. Cladding creep and hydride reorientation may also potentially affect the transportation of HBF depending on if the fuel is being transported from the spent fuel pool or from dry storage.

The expected effects of creep and radial hydrides are discussed in ISG - 11, Revision 3. The staff developed ISG - 11, Revision 3, in order to provide guidance to the staff on maximum cladding temperatures and stresses that result in acceptable operational considerations when loading spent fuel into storage casks and transportation packages. In ISG - 11, Revision 3, the staff identified creep deformation as the most likely mechanism for cladding breach in storage and hydride reorientation as potentially having a significant effect on the cladding behavior during accidents. The temperature and stress conditions in ISG - 11, Revision 3, were determined to limit creep. Based on the data available at that time, it was also determined that these temperatures and stresses would prevent hydride reorientation from occurring. However, subsequent research has shown that hydrides may still reorient radially even if the temperatures and stresses indicated in ISG - 11, Revision 3, are not exceeded [1-3].

Radial hydrides are further discussed in research results [1] that have shown that if temperatures and pressures during pre-storage drying-transfer operations and early stage storage are high enough to dissolve hydrides, then radial hydrides could precipitate as the material cools following pre-storage operations and during dry cask storage. Radial hydrides can represent an additional embrittlement mechanism that could potentially result in cladding failure if the cladding temperature decreases below a ductile-to-brittle transition temperature and the rods are subjected to stresses higher than the fuel's mechanical limit. Mechanical properties that account for the extent of radial hydride precipitation and the ductile-to-brittle transition temperature are important for the evaluation of cladding performance. Research results have also shown that both the extent of radial hydride precipitation and the ductile-to-brittle transition temperature are highly dependent on cladding material, metallurgical state, hydrogen content, stress at peak cladding temperature, and peak cladding temperature. Recent research indicates that the hydride reorientation results in a shift of the ductile-to-brittle transition temperature of the cladding to a higher value [1].

Knowledge of mechanical properties that account for the effect of radial hydrides, including the extent of radial hydride precipitation and the ductile-to-brittle transition temperature, is required to perform structural analyses. These structural analyses determine the potential fuel configurations of fuel assemblies resulting from the inertia loads exerted on the fuel rods during operational and accident conditions. Criticality, containment/confinement, thermal, and shielding safety evaluations require a description of these potential fuel configurations.

When accounting for the effect of radial hydrides on structural analyses, staff expects that radial hydrides will not influence the cladding behavior when a cladding tensile stress field associated with the rod bending due to inertia is parallel to both radial and circumferential hydrides. This is currently being confirmed by tests run by the NRC at the Oak Ridge National Laboratory. Because of this, it is reasonable to assume that only inertia loads which result in a large tensile stress perpendicular to the radial hydrides require consideration in a structural evaluation. Therefore, only a possible secondary, pinch-mode cladding breach failure [6] should be

assessed for fuel assembly structural performance. This pinch-mode could potentially occur only during potential transportation hypothetical accident conditions with 30-ft free drops.

Although radial hydrides develop in HBF cladding during the vacuum drying process and in dry storage, their effect on the cladding mechanical properties should be taken in consideration for transportation of HBF from either the spent fuel pool or dry storage. In addition to the effect of radial hydrides, the effect of creep on the cladding mechanical properties should also be taken into consideration to determine the behavior of the fuel assemblies during direct transport from the pool when the fuel temperature is high. If the fuel temperature is high when direct loading takes place, the ensuing creep may cause a significantly lowered ductile-to-brittle transition temperature as the fuel cools. The ability to predict the effects of hydride reorientation and creep on the cladding during transportation is required to ensure that the contents meet the conditions of the CoC, which are based on safety analyses to demonstrate compliance with 10 CFR 71.33(b)(3), 10 CFR 71.55(d)(2), 10 CFR 71.55(e)(1), and 10 CFR 71.89.

Regulations affecting HBF dry storage are 10 CFR 72.122(h) and 10 CFR 72.122(l). In these regulations, 10 CFR 72.122(h) requires protection of fuel cladding against gross rupture, unless the spent fuel is otherwise confined such that degradation of the fuel during storage will not pose operational safety problems with respect to its removal from storage. Additionally, 10 CFR 72.122(l) requires ready retrieval of spent fuel. As discussed in ISG – 11, Revision 3, creep is the primary breach mechanism for spent fuel cladding. If the temperature and stress conditions addressed in ISG - 11, Revision 3, are met, there is reasonable assurance that spent fuel cladding will not experience gross rupture under normal and off-normal storage conditions since, due to the design of the fuel rods, creep is a self-limiting mechanism. However, as results from the Idaho cask demonstration provided confirmation to continue licensing LBF, a HBF demonstration cask is expected to provide similar confirmation on the effects of creep and radial hydrides on HBF for the initial 20-year dry storage licensing term and beyond, and, to an extent, the transportation of HBF after dry storage.

The challenges of demonstrating compliance with the storage and transportation regulations when reviewing designs for HBF are also discussed in the U.S. Department of Energy's report, "Gap Analysis to Support Extended Storage of Used Fuel," [7] and other documents, which identify that additional data are needed to enhance the understanding of HBF cladding performance with additional confidence.

## **SUMMARY OF ISSUE**

The staff developed licensing approaches that would provide reasonable assurance for demonstrating compliance with regulations in HBF applications for storage and transportation. In developing these acceptable approaches, the staff modified the approach currently employed for LBF by including the ability to review HBF storage and transportation using a defense-in-depth licensing approach as will be discussed in the following sections. However, as further operational experience on HBF behavior in storage or short-term experimental and/or operational data on HBF behavior during transportation becomes available to reduce uncertainty, the staff anticipates that this approach could more closely align with that of LBF, in that the defense-in-depth licensing approach will no longer be necessary. Although this RIS outlines approaches the staff finds acceptable, the applicant may consider and demonstrate other approaches that the staff may also find acceptable upon review.

The licensing approaches discussed below consider two principal factors when evaluating normal, off-normal, and accident scenarios for storage, and normal and hypothetical accident conditions for transportation: (1) whether the fuel has been placed in a damaged fuel can, and (2) the length of time it has been in storage. Application of these general approaches for storage and transportation is shown schematically in Enclosures 1 and 2, respectively.

### *Storage*

Enclosure 1 shows a high-level diagram of acceptable licensing approaches for storage of HBF.

First, the applicant's safety analysis should consider if the fuel has been placed in a damaged fuel can [8] and has therefore been "canned." For canned HBF, as the fuel is expected to remain confined to the can, the applicant may perform bounding safety analyses assuming full reconfiguration inside the fuel can. In this case, however, the structural performance of the fuel can should also be evaluated.

Next, for fuel that has not been placed in a damaged fuel can, the applicant's safety analysis should consider the length of the storage period, specifically, whether the fuel has been in dry storage for more than 20 years.

For the initial dry storage of HBF for up to 20 years, the current guidance in ISG - 11, Revision 3, remains acceptable.

For HBF in dry storage beyond 20 years, guidance in ISG – 24, "The Use of a Demonstration Program as a Surveillance Tool for Confirmation of Integrity for Continued Storage of High Burnup Fuel beyond 20 Years," (ADAMS Accession No. ML14058B166) provides an acceptable way to demonstrate compliance with the regulations to meet normal and off-normal conditions of storage. This aligns with the approach currently used for LBF in that confirmation is provided by results from a demonstration cask. However, if data from a demonstration cask is unavailable, the applicant should confirm that the initial conditions of the HBF going into the next storage period are as expected, and perform conservative safety analyses assuming fuel failure which adds defense-in-depth. An acceptable means of confirmation is the examination of a lead system that provides data on the cask and its internals after the initial storage period. Upon obtaining this confirmation, the safety analyses should show that the storage cask meets the regulatory acceptance criteria when assuming fuel failure in thermal, confinement, criticality, and shielding for normal and off-normal conditions. These confirmations obtained, either from the demonstration cask or through a possible lead system examination, provide assurance of the retrievability of the stored HBF.

For applications involving HBF in dry storage beyond 20 years, appropriate materials property data should be used to perform structural analyses to meet storage accident conditions. If data are unavailable for the specific cladding type, the applicant should perform a safety analysis that assumes fuel failure in evaluating thermal, confinement, criticality, and shielding performance.

These safety analyses should be performed in a similar manner to the confinement analyses that are done for LBF for normal, off-normal, and accident storage conditions, which use fuel failure fractions of 1 percent, 10 percent, and 100 percent, respectively. Applying these fuel failure fractions would provide reasonable assurance of safety and defense-in-depth in the case of limited data availability. These values, although considered to be conservative, are not

mandatory and the applicant can perform the defense-in-depth analyses assuming other justified values of fuel failure percentages. Release fraction values used as part of the confinement analysis for non-leaktight casks should be experimentally justified.

### *Transportation*

Enclosure 2 shows a high-level diagram of acceptable licensing approaches for transportation of HBF.

First, the applicant's safety analysis should consider if the fuel has been placed in a damaged fuel can [8] and has therefore been "canned." For canned HBF, the applicant may perform bounding safety analyses assuming full reconfiguration inside the fuel can. In this case, however, the structural performance of the fuel can should also be evaluated.

For fuel that has not been placed in a damaged fuel can, the applicant's safety analysis should consider whether the fuel has been in dry storage or is shipped directly from the spent fuel pool.

For the transportation of HBF after dry storage, direct inspection of the fuel may not be necessary. Cladding material properties appropriate to the transportation temperature could be used to model the structural behavior of the fuel during normal conditions of transportation and hypothetical accident conditions. When the cladding temperature is above the ductile-to-brittle transition temperature, where the cladding remains more ductile, structural analysis of the fuel should use properties of the cladding with only circumferential hydrides. However, if prior to transport the fuel has been cooled for a substantial period of time, the fuel inside the package may be lower than the ductile-to-brittle transition temperature. In this case, the applicant should provide defensible mechanical properties of the HBF cladding with radial hydrides to use in the structural analysis to evaluate fuel failure in the 30-ft free drop hypothetical accident condition scenario. This data should be representative of the cladding material type, hydrogen content, maximum temperatures, and maximum stresses. In both situations, the applicant should provide data to defend the cited ductile-to-brittle transition temperature, and justify that the calculated temperatures for the cladding are conservatively low.

When data for mechanical properties of the HBF cladding with radial hydrides are not available, an acceptable conservative, defense-in-depth approach for performing safety analyses is to assume some percentage of fuel failure for normal conditions of transportation and hypothetical accident conditions. For normal conditions of transportation, safety analyses assuming a 3 percent fuel failure would be considered conservative in evaluating the thermal, containment, criticality, and shielding performance. For hypothetical accident conditions, safety analyses assuming 100 percent fuel failure would be considered conservative for the thermal, containment, criticality, and shielding disciplines. These values, although considered to be conservative, are not mandatory and the applicant can perform the defense-in-depth analyses assuming other justified values of fuel failure percentages. Release fraction values used as part of the containment analysis for non-leaktight packages should be experimentally justified.

Until sufficient data are available, loading and unloading operating procedures should provide steps to confirm that HBF meets the CoC conditions prior to and after transport. As discussed previously, fuel is not expected to reconfigure if it has not experienced a pinch mode and, as such, these procedures are expected to confirm the ability to transport HBF during normal conditions of transportation. In addition to this confirmation provided through the transportation

operating procedures, confirmation may be provided when the demonstration cask as described in the storage licensing approach is transported.

For transportation of uncanned HBF loaded directly from the spent fuel pool, an acceptable approach is to use guidance provided in ISG - 11, Revision 3, to determine the maximum cladding temperature, provide a justifiable ductile-to-brittle transition temperature, and to verify the minimum temperature remains above the ductile-to-brittle transition temperature for the entire duration of transportation [5]. If these conditions are met, then the mechanical properties of the cladding material with circumferential hydrides may be used. If sections of the fuel cladding do not remain above the ductile-to-brittle transition temperature, additional steps would be necessary.

In addition to this RIS, within the next few years, the staff anticipates issuing additional guidance on dry cask storage system CoCs, ISFSI licenses, and transportation package CoCs containing HBF. Additional guidance to be issued include an update to NUREG-1927, "Standard Review Plan for Renewal of Spent Fuel Dry Cask Storage System Licenses and Certificates of Compliance," and a guidance document for development of spent fuel storage system aging management programs.

## **BACKFITTING AND ISSUE FINALITY DISCUSSION**

This RIS is intended to set forth the NRC's position regarding acceptable approaches for demonstrating regulatory compliance in applications for dry storage cask CoCs, CoCs for transportation packages, and specific ISFSI licenses involving HBF. The RIS is addressed to applicants of ISFSI licenses, and applicants of CoCs for ISFSI and transportation casks issued under 10 CFR Part 71 and 72. This RIS requires no action or written response beyond that already required by the NRC regulations. As explained below, this RIS does not represent backfitting or issue finality provisions under 10 CFR Parts 71 or 72.

### *No backfitting protection in 10 CFR Part 71*

There are no backfitting or issue finality provisions in Part 71. Therefore, no applicant, licensee or holder of a CoC under Part 71 is protected by any backfitting provision in Part 71. Although nuclear power plant licensees may also be a holder of a general license for a transportation cask as authorized by the NRC under Part 71, the discussion in this RIS is provided to holders of general licenses only for information. The RIS is not directed at activities controlled by the nuclear power plant operating license (including a Part 52 combined license). Hence, the backfitting and issue finality provisions in the Backfit Rule, 10 CFR 50.109 and Part 52 are inapplicable to the nuclear power plant licensee who use the transportation cask generally licensed under Part 71.

### *No backfitting protection for CoCs or applicants under Part 72.*

The RIS does not address matters which constitute backfitting under 10 CFR 72.62. This RIS sets forth the NRC's position regarding acceptable approaches for demonstrating regulatory compliance in applications for CoCs and specific ISFSI licenses under Part 72. Neither holders of nor applicants for CoCs fall within the backfit provision in Part 72; nor do applicants for ISFSI licenses, as discussed in greater detail below.

*The RIS positions do not apply to holders of early site permits, design approvals, design certifications, and combined licenses under Part 52, or holders of operating licenses under Part 50*

The RIS does not apply to holders of early site permits, design approvals or design certifications. The matters which are resolved and accorded issue finality under the applicable issue finality provisions of Part 52 do not extend to the safety and security issues addressed in the spent fuel storage and transportation cask systems which are the subject of this RIS. Although an applicant for an ISFSI license who is an addressee of this RIS may also be a Part 52 combined license holder or a holder of a Part 50 operating license, the discussion in this RIS is not directed to nuclear power plant licensees as a general licensee. The RIS is not directed at activities controlled by the nuclear power plant operating license. Hence, the backfitting and issue finality provisions in the Backfit Rule, 10 CFR 50.109 and Part 52 are inapplicable to the nuclear power licensees who are also holders of either specific or general ISFSI licenses under Part 72.

*Backfitting and issue finality do not – with limited exceptions not applicable here – protect current or future applicants*

Applicants and potential applicants are not, with certain exceptions, protected by either the Backfit Rule or any issue finality provisions under Part 52. This is because neither the Backfit Rule nor the issue finality provisions under Part 52 – with certain exclusions discussed below – were intended to apply to every NRC action which substantially changes the expectations of current and future applicants. The exceptions to the general principle are applicable whenever an applicant references a Part 52 license (e.g., an early site permit) and/or NRC regulatory approval (e.g., a design certification rule) with specified issue finality provisions. However, the matters covered in this RIS are not subject matters or issues for which issue finality protection is provided.

For these reasons, the NRC did not prepare a backfit analysis for this RIS or further address the issue finality criteria in Part 52.

#### **FEDERAL REGISTER NOTIFICATION**

A notice of opportunity for public comment on this RIS was published in the *Federal Register* on Month XX, 2015 (80 FR XXXX).

#### **CONGRESSIONAL REVIEW ACT**

[Discussion to be provided in the final RIS]

#### **PAPERWORK REDUCTION ACT STATEMENT**

This RIS does not contain new or amended information collection requirements that are subject to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et seq.). Existing requirements were approved by the Office of Management and Budget, approval numbers 3150-0008 and 3150-0132.

## **PUBLIC PROTECTION NOTIFICATION**

The NRC may not conduct or sponsor, and a person is not required to respond to, an information collection unless the requesting document displays a currently valid OMB control number.

## **CONTACT**

This RIS requires no specific action or written response. Please direct any questions to the technical contact listed below or the appropriate NRC office.

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## **Enclosures:**

1. Approach for Review of High Burnup Fuel Storage
2. Approach for Review of High Burnup Fuel Transportation
3. References



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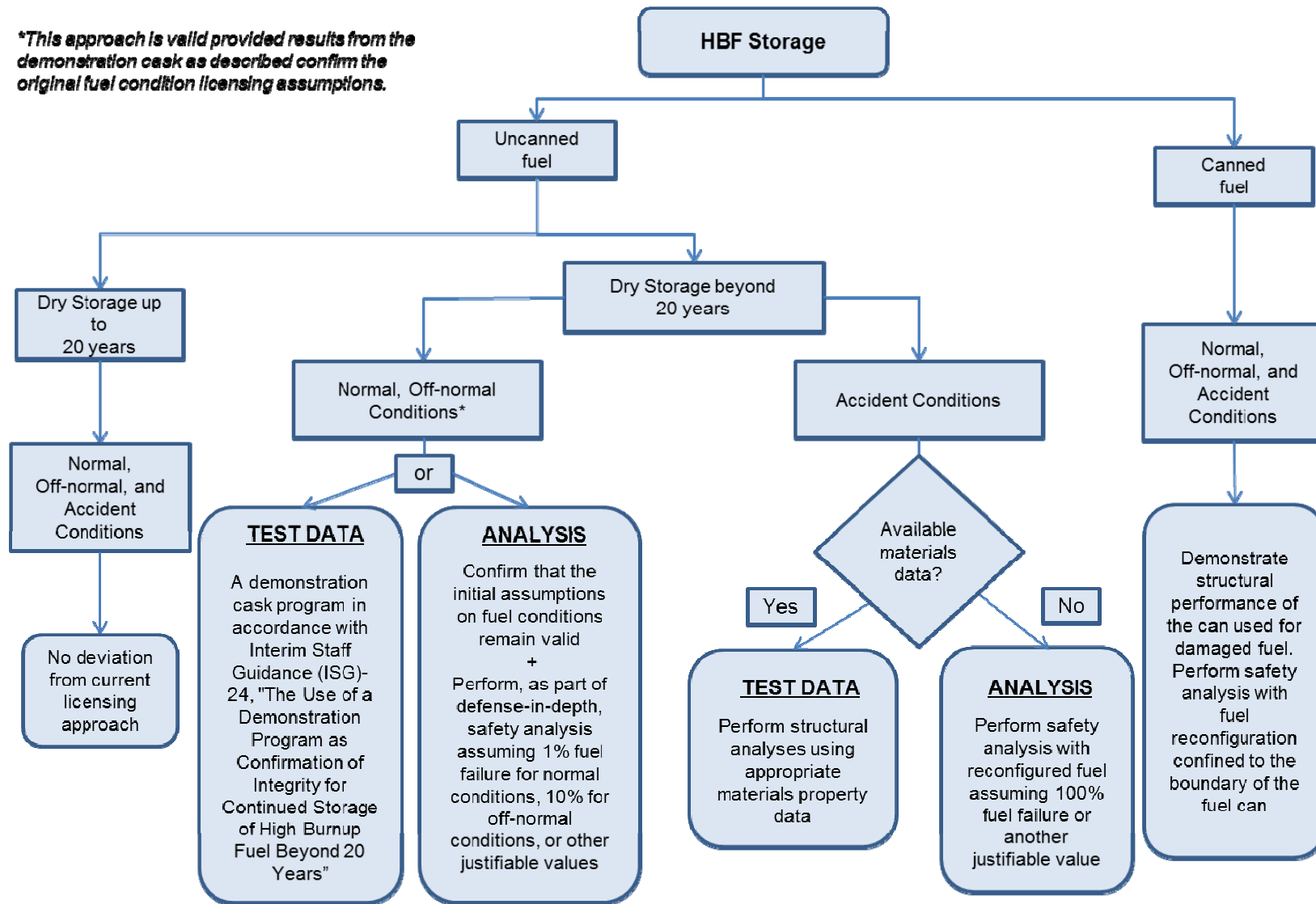
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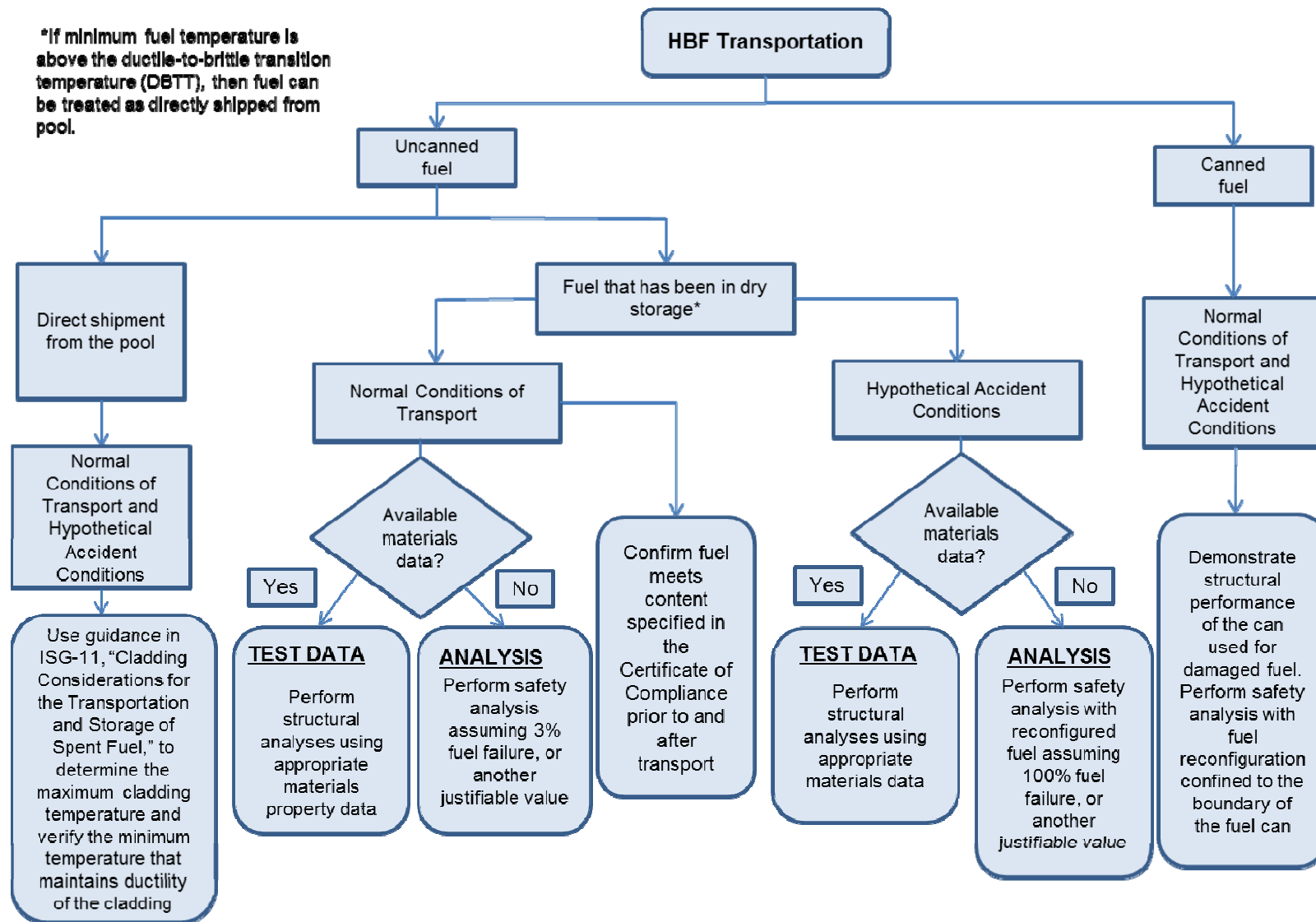
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## High Burnup Fuel Storage Licensing Approach

*\*This approach is valid provided results from the demonstration cask as described confirm the original fuel condition licensing assumptions.*



## High Burnup Fuel Transportation Licensing Approach



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## REFERENCES

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8. Interim Staff Guidance 1 (ISG-1), Revision 2, "Classifying the Condition of Spent Nuclear Fuel for Interim Storage and Transportation Based on Function," Division of Spent Fuel Storage and Transportation, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, D.C., May 2007.