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October 25, 2002

MEMORANDUM TO: SFPO Staff Members

FROM: E. William Brach, Director **/RA/**
Spent Fuel Project Office
Office of Nuclear Material Safety
and Safeguards

SUBJECT: ISSUANCE OF REVISION 1 OF SFPO DIRECTOR'S INTERIM STAFF GUIDANCE DOCUMENT-1

Attached for your use and information is Revision 1 of the Spent Fuel Project Office (SFPO) Director's Interim Staff Guidance Document -1 (ISG-1). This revised interim staff guidance concerns the issue of "Damaged Fuel."

This document is being provided to ensure consistent reviews by the SFPO staff. If you have any comments or questions about the attached guidance document, please contact your immediate supervisor.

Attachment: ISG-1, Rev. 1

CONTACT: Geoffrey Hornseth, SFPO/NMSS
301-415-2756

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Spent Fuel Project Office
Interim Staff Guidance - 1
Revision 1
Damaged Fuel

Issue:

This ISG provides definitions of damaged fuel, outlines how damaged fuel is considered in storage or transportation analyses, and provides guidance for classifying spent fuel as either damaged or intact prior to placing the fuel into storage or transportation casks.

It is necessary to define damaged fuel and specify special conditions for its handling, storage, and transportation in order to accomplish several requirements:

(1) Confine gross fuel particles that may escape from damaged cladding.

(2) Facilitate retrieval from a storage or transportation cask.

(3) Confine damaged fuel assemblies within a known volume to facilitate criticality control, maintain dose limits, and control thermal loads within the cask.

This revision of ISG-1 incorporates the following changes:

(1) Expands the definition of damaged spent fuel beyond the confinement-based definition of cladding defects greater than hairline cracks or pinholes. The expanded definition addresses other degradation modes, and, most significantly, requires evaluation of spent fuel that may contain material or mechanical conditions which could lead to fuel failure under some conditions such as the stresses inherent to the hypothetical accident conditions of transportation.

(2) Defines a damaged-fuel-can.

(3) Provides guidance for a licensee to demonstrate the condition of spent fuel as damaged or intact.

(4) Allows for an alternative to placing some forms of damaged fuel into a damaged-fuel-can if it can be shown through analysis that the assembly in question is capable of withstanding all design loads without reconfiguring.

(5) Clarifies when criticality analyses are required of damaged fuel assemblies.

This revision to ISG-1 is necessary due to the expanded definition of damaged fuel that has evolved over the course of storage and transportation cask license reviews. The staff recognized that the existing cladding-defect-based definition of damaged fuel failed to capture other degraded fuel conditions such as missing grid spacers. More significantly, it failed to address fuel assembly structural performance under certain design conditions, especially during the hypothetical accident conditions of transportation.

Structural performance of the cladding and the entire assembly is related to the design conditions. This revised guidance recognizes that the Part 72 normal and design basis events place entirely different stresses upon the spent fuel than those in the Part 71 normal and hypothetical accident conditions. These differing design conditions require a damaged fuel definition that is based upon whether the fuel is being prepared for storage or transportation. This differentiation recognizes the licensees' varying needs by allowing fuel classification as damaged or intact for storage-only, with later analysis against Part 71 requirements when the need arises.

In addition to these design condition differences, the staff recognizes that some high burn-up fuel that could be classified as intact under storage-only conditions may not have sufficient cladding or structural integrity to withstand the more severe stresses of a transportation hypothetical accident. Consequently, some "intact" high burn-up fuel placed in storage casks may need to be evaluated in the future against the more severe stresses inherent to the hypothetical accident conditions of transportation when such fuel is to be transported.

Regulatory Basis:

The spent fuel transportation and storage regulations (10 CFR Parts 71 and 72) have the following common safety objectives:

(1) Ensure that doses are less than the limits prescribed.

(2) Maintain subcriticality under specified conditions of storage and transportation.

(3) Ensure there is adequate confinement of the spent fuel during storage and transportation.

Additionally, Part 72 regulations and operational considerations under Part 71 require that the spent fuel be readily retrievable after specified conditions of storage or transportation.

For storage, 10 CFR 72.124 and 72.236(c) require that the configuration of the spent fuel geometry be maintained when feasible to assure subcriticality under all credible normal and design basis events of storage. Parts 72.122 (h)(1), 72.122(l) and 72.236(m) seek to ensure safe fuel storage and handling and to minimize post-operational safety problems with respect to retrievability of the fuel from the storage system.

During normal conditions of transportation, the geometric form of the spent fuel should not become substantially altered. Also, for normal conditions, the licensee must assure that there will be no loss or dispersal of spent fuel, no significant increase in external surface radiation levels, and no substantial reduction in the effectiveness of the spent fuel package as required by 10 CFR 71.43(f).

Under the hypothetical accident conditions of transportation, the licensee must assure that design loads imposed upon the fuel assemblies do not lead to a failure that would invalidate design assumptions used to satisfy the criticality control requirements of 10 CFR 71.55 and the shielding and containment requirements of 10 CFR 71.51.

Applicability

This guidance applies to reviews of dry cask storage systems and transportation casks conducted in accordance with NUREG-1536, “Standard Review Plan for Dry Cask Storage Systems” (January 1997), NUREG-1567, “Standard Review Plan for Spent Fuel Dry Storage Facilities” (March 2000), or NUREG-1617, “Standard Review Plan for Transportation Packages for Spent Nuclear Fuel” (March 2000).

This revision supercedes ISG-1, Revision 0, in its entirety.

Definitions

Damaged fuel - Spent nuclear fuel is considered damaged for storage or transportation purposes if it manifests any of the following conditions that result in either compromise of cladding confinement integrity or rearrangement (reconfiguration) of fuel bundle geometry:

1) The fuel contains known or suspected cladding defects greater than a pinhole leak or hairline crack that have the potential for release of significant amounts of fuel particles into the cask.

2) The fuel assembly:

a) Is damaged in such a manner as to impair its structural integrity;

b) Has missing or displaced structural components such as grid spacers;

c) Is missing fuel pins which have not been replaced by dummy rods which displace a volume equal to or greater than the original fuel rod;

d) Cannot be handled using normal (i.e., crane and grapple) handling methods. (Exception: fuel assemblies with repaired lifting bails, support caps, or support tubes, etc., which permit normal handling may be classified as intact. See later discussion.)

3) The fuel is no longer in the form of an intact fuel bundle and consists of, or contains, debris such as loose fuel pellets, rod segments, etc.

4) The fuel assembly structural hardware or cladding material properties are in a degraded condition such that its ability to withstand the normal and design basis events of storage (for storage-only casks), or the normal and hypothetical accident conditions of transport as intact fuel is questionable. This condition could apply to some high burn-up assemblies. The NRC is sponsoring research to verify the material properties of high burn-up assemblies.

Note: Due to the very different design conditions of storage versus transportation, a (primarily high burn-up) fuel assembly classified as intact under storage-only conditions may require re-analysis against the more severe conditions of transportation prior to being transported. Fuel classified as damaged under storage-only conditions would remain classified as damaged under transportation conditions.

5) The fuel exhibits any other condition that is judged to be adverse to the criteria of confining radioactive material, controlling criticality, maintaining shielding, dose, or thermal limits or is adverse to the design conditions of the cask.

Damaged-Fuel-Can - A metal enclosure sized to contain one fuel assembly. Damaged fuel is placed inside a damaged-fuel-can ("canned") prior to loading it into a dry storage or transportation cask. The can must be individually removable from the cask using normal fuel handling methods (crane and grapple). The can may use a mesh screen to achieve gross particulate confinement but allow water drainage during wet loading operations. The purpose of a damaged-fuel-can is to confine gross fuel particles, debris, or damaged assemblies to a known volume within the cask to facilitate criticality, shielding, and thermal requirements and permit normal handling and retrieval from the cask. The damaged-fuel-can may need to contain neutron absorbing materials to prevent criticality if many damaged assemblies are co-located in a single cask.

Discussion

Spent fuel is classified as either damaged or intact in accordance with the preceding definitions and the guidance following. Use of the guidance for classification of damaged or intact fuel will reasonably assure that the fuel is properly identified and handled to meet the safety and regulatory requirements governing Parts 72 and 71. Normally, when fuel is classified as damaged, it must be placed into a damaged-fuel-can prior to being loaded into a storage or transportation cask unless additional analyses can show that no reconfiguration of the fuel assembly or no gross failure of the cladding will occur. If such analyses demonstrate that the otherwise "damaged" fuel assembly will maintain cladding integrity and normal configuration under the design loads, then the requirement for placing that assembly into a damaged fuel can may be omitted. See later discussion under "Alternative Method for Classifying Fuel (Performance Based)".

<u>Storage Accident Analyses</u>

When storage accident conditions/analyses are referred to in this document, the following special conditions apply:

1) The structural evaluation of the spent fuel shall consist of a fuel assembly buckling analysis for credible end-drop accidents and bending analyses for credible tip-over or side-drop accidents. Consideration of defects such as loss of cladding thickness due to oxidation should be included in the analyses. Fuel assemblies that do not fail under these loads are considered structurally intact.

2) Criticality analyses for both intact and canned damaged fuel should be in accordance with the requirements of 10 CFR 72.124.

<u>Criticality, Dose Limits, and Thermal Control of Damaged Fuel</u>

The potential reconfiguration of damaged fuel within the damaged-fuel-can must be analyzed to demonstrate that the cask/fuel meet the criticality, dose, and thermal limits of normal and design basis events of storage and/or normal and hypothetical accident conditions of transportation. Bounding analyses may be performed. A criticality analysis for canned damaged fuel is typically performed by assuming a non-mechanistic redistribution of the fuel pellets into the most reactive geometry and assessing against the staff accepted K-effective limit of 0.95. Shielding and thermal analyses should similarly assume a worst case or bounding configuration (not necessarily the same for each analysis) of the canned fuel.

Methods for Classifying Fuel

The following steps describe the considerations and criteria that may be used to classify fuel as either intact or damaged. Since this guidance does not attempt to envision all possible circumstances, the licensee has the responsibility to develop a logically supported inspection plan appropriate for the fuel in question.

Along with the demonstration of cladding integrity, the structural integrity of a fuel assembly must also be demonstrated. Structural integrity assessments include consideration of assembly hardware items such as grid straps, grid spacers, and related components that maintain the geometric form of the assembly. Existing in-core and handling records may be used for the classification, or additional examinations may be performed to classify the fuel.

A fuel assembly must meet the criteria for both intact cladding and structural integrity to be classified as intact.

1.0 Consideration of Cladding Condition

1.1 Classification Based Upon Existing Records

1.1.1 If the fuel has no indication of operating leakage based upon core history records, handling records, and no unusual conditions are evident, then the fuel may be classified as intact (undamaged). "Unusual conditions" means licensees should consider, for high burn-up fuels, irradiation embrittlement or other structural integrity-altering degradation (hydride lenses, excessive oxidation, oxide spalls) that could affect the ability of the fuel to remain intact under design basis conditions for storage and/or transport.

1.1.2 If operating records, such as core history, indicate leakage or other damage, then the fuel must be considered damaged unless additional analysis of the information demonstrates the nature of the damage is small. Such analyses could consider the in-core radionuclide differences between small, pinhole-like cladding leaks and larger cladding breaches.

1.1.3 Fuel in the form of debris (rod segments, pellets, etc.) or an assembly containing debris is classified as damaged fuel.

1.2 Classification Based Upon Additional Examination

1.2.1 Fuel lacking adequate records should be further examined to demonstrate its condition. Testing methods such as sipping, UT, etc., may be used to evaluate the fuel for cladding damage. The testing method that is selected must be appropriate for the fuel being examined and the type of damage to be detected. When developing an inspection plan, the fuel design, history, and condition should be considered. Items of consideration should include but are not limited to: burn-up, decay time, and cladding condition (oxide spalls, hydride lenses, etc.). If the examination results indicate that the fuel has cladding damage greater than pinhole leaks or hairline cracks, it is classified as damaged.

2.0 Classification of Fuel Structural Integrity

2.1 A fuel asembly NOT capable of being handled and moved by normal means (i.e. crane and grapple) must be classified as damaged. Assemblies with modified or repaired top bails, etc., may be classified as intact provided no other damage is present.

Note: an assembly capable of being handled by normal means is insufficient justification by itself for being classified as intact.

2.2 Fuel assemblies with missing or displaced structural elements such as grid spacers, grid straps or similar hardware must be classified as damaged.

2.3 Degraded mechanical/material properties (structural components or cladding).

2.3.1 If the fuel assembly or cladding is in such condition that its ability to withstand the normal and design basis events of storage or the normal and hypothetical accident conditions of transport, intact, is questionable, it shall be classified as damaged. Intact means no geometric rearrangement of the fuel assembly or no gross failure of the cladding. Licensees should consider the effects of irradiation embrittlement and other structural integrity-altering degradation (hydride lenses, oxide spalls) that could affect the ability of the fuel to remain intact.

2.4 Fuel Assemblies That Have Undergone Modifications

2.4.1 A fuel assembly shall be classified as damaged if fuel rods or structural components have been removed, the assembly has been altered such that its structural integrity is adversely affected under the design basis storage and/or transportation conditions, or normal handling can not be accomplished.

2.4.2 A fuel assembly with missing fuel pins shall be classified as damaged unless criticality analyses demonstrate an acceptable value of K-effective with the fuel pins missing. Structural analyses should demonstrate the assembly remains intact under design basis storage and/or transportation conditions.

2.4.3 Fuel assemblies that are reconstituted and complete, contain undamaged components of original type or equivalent, and are of original geometry, are considered intact.

Repairs to Assembly Lifting Hardware

Fuel assemblies that have experienced damage to the lifting bail or assembly end cap are considered damaged unless modified to permit normal handling. Modifications to the lifting bail or modifications to the assembly end cap to permit handling by normal means may permit its classification as intact fuel (assuming no other types of damage are present). However, before so classifying any such assembly, the licensee must evaluate the repair method. The evaluation must reasonably demonstrate that the repair will not degrade as a result of exposure to the high temperatures of dry storage or transportation (relative to spent fuel pool temperatures) or other design conditions such as the hypothetical drop accident of transportation.

Fuel bundles so classified as intact should be documented and the documentation included as part of the documentation for that specific assembly. The documentation should include a description of the repair design features and a record of where such bundles are located within a cask.

Any special tooling required for lifting such bundles should accompany the cask and be provided to any organizations responsible for future fuel handling activities.

Note that compliance with these provisions for repaired lifting hardware does not imply that the Department of Energy will accept this fuel as “standard fuel” at a permanent disposal repository.

Alternative Method for Classifying Fuel (Performance Based)

A fuel assembly otherwise classified as damaged by this guidance may be analyzed against storage or transportation conditions to determine if it may be treated as intact fuel. This approach could allow the licensee to avoid the requirement for using damaged fuel cans in some cases. Specific evaluation methods are not delineated herein but they should encompass a structural integrity or flaw tolerance analysis to determine fuel assembly performance under the appropriate storage or transportation conditions. Such analyses must demonstrate with reasonable assurance that the damaged assembly can withstand those conditions without loss of cladding confinement capability or becoming reconfigured. Since there is no staff-approved methodology for performing such evaluations, they must be reviewed and approved on a case-by-case basis by the NRC staff. When an evaluation is used to justify not canning the damaged fuel, then it shall be documented and retained as part of the record for each fuel assembly.

Records

Records documenting the classification of fuel shall comply with the provisions of 10 CFR 72.174, “Quality Assurance Records” and 10 CFR 72.72, “Material Balance, Inventory, and Records Requirements for Stored Material.”

Quality Assurance

Activities related to inspection, evaluation, and documentation of damaged fuel for dry storage shall be performed in accordance with an NRC-approved quality assurance program as required in 10 CFR Part 72, Subpart G, "Quality Assurance."

Recommendation

The staff recommends that: (1) the definitions in NUREG-1536, NUREG-1567, and NUREG-1617 be revised to incorporate the definitions listed above, (2) the appropriate chapters of each NUREG be revised to include the discussion section of this ISG, and (3) an appendix to each NUREG be added to include requirements for classifying damaged spent fuel.

Approved ***/RA/*** 10/25/02
E. William Brach Date