A STANDARD FOR STORAGE AND TRANSPORT OF DAMAGED SPENT FUEL

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ABSTRACT

The paper describes the background that led to development of the Nuclear Regulatory Commission's April 1984, Director's Decision on failed and damaged spent fuel, DD-84-9. Some examples of damaged fuel transports and the recently issued NRC interim staff guidance on damaged SNF, ISG-1, are discussed. These preliminary topics form the basis for discussion of the need, development and status of an American National Standards Institute standard, ANSI N14.33, for damaged spent fuel.

INTRODUCTION

A small fraction of spent nuclear fuel (SNF) may be damaged. Damage may include defects in fuel cladding or assembly hardware. Because SNF damage could affect the radiological safety functions of a transport cask or storage system, it is of concern to utilities, shippers, regulators, and operators of other facilities that handle SNF.

In 1984, the Nuclear Regulatory Commission (NRC) issued a Director's Decision (DD-84-9) that addressed transport of damaged fuel [1]. NRC determined that all spent fuel, if shipped dry, had to be contained in non-oxidizing containment cavities and canned if damaged. DD-84-9 gave the NRC staff a mechanism for controlling shipments of damaged spent fuel, but did not provide guidance for implementing requirements of the decision.

There have not been many domestic shipments of commercial spent nuclear fuel since DD-84-9 was issued in April 1984. Of those, there have been fewer shipments of damaged spent fuel. Therefore, experience with the treatment of damaged fuel for transport is sparse.

The NRC has recently issued interim staff guidance, ISG-1, on transport and storage of damaged spent fuel [2]. The NRC guidance provides a brief definition of damaged fuel, canning requirements for storage and transport, special containment requirements for transport, and guidance on how licensees can demonstrate fuel condition. The guidance is helpful in identifying what has to be done to store and transport damaged spent fuel, but does not give specific, practical instruction on how to implement the guidance. In response to this need for specific direction, the American National Standards Institute (ANSI) has approved a proposal for developing a damaged fuel standard, and forming a writing group (WG).

The paper will describe the events that led to development of DD-84-9, and discuss some examples of damaged fuel transports. The paper will discuss the guidance given by the NRC in ISG-1; and the need, development and status of a proposed ANSI standard, ANSI N14.33, for damaged spent fuel.

BACKGROUND

The NRC Director's Decision, DD-84-9, signed by John G. Davis, Director, Office of Nuclear Materials Safety and Safeguards, April 13, 1984, addressed the issue of failed and damaged fuel and its potential impact on transport safety. The decision was issued in response to a request from the Sierra Club under 10 CFR §2.206 [3].

The Sierra Club's request was motivated by a May 1980 incident involving an irradiated fuel assembly with known severe cladding failure that was shipped to Battelle Columbus Laboratory (BCL) for examination. Rod failure included 4-5 foot long cracks approximately $1/8^{th}$-inch wide in stainless steel cladding. The fuel was shipped to BCL dry in a Model NFS-4 cask. Upon removal of the cask lid while the cask was submerged in a receiving pool, material emanated from the cask, resulting in contamination of pool water and airborne contamination within the cask handling area. It was later determined that the fuel may have reached temperatures of up to $285^{o}C$ in an air environment during shipment.

Although the specific recommendations offered by the Sierra Club in their request were not implemented by NRC, an evaluation was conducted and remedial actions proposed and taken to preclude recurrence of the situation. The NRC evaluation, results, and conclusions are described in an NRC Research Information Letter [4]. NRC concluded that the combination of sufficiently high temperature and the presence of oxygen due to exposed fuel pellets from damaged fuel cladding led to oxidation of the UO_2. The oxidation of UO_2 to the less dense and higher oxidation state, U_3O_8, resulted in spalling and particulate generation. Although the NRC evaluation determined that containment remained adequate for transport, they were concerned about handling the damaged SNF at its destination.

The NRC decided to use a two-stage remedial action strategy. First, all irradiated fuel, regardless of cladding state, if shipped dry, would have to be transported in casks with containment cavities filled with inert, non-oxidizing gas (e.g., helium, argon, nitrogen). Second, fuel assemblies known or suspected of being failed should be canned for shipment. NRC Certificates of Compliance for spent fuel casks were revised to require inert (non-oxidizing) gas in their containment cavities, and to prohibit shipment of failed fuel. A notable exception to the prohibition against shipment of failed fuel was a specific configuration of an approved cask design, the Model NLI-1/2, which had a secondary containment closure. The wording used as a condition of approval, which is still used today, was, "Known or suspected failed fuel and fuel with cladding defects greater than pin holes and hairline cracks are not authorized."

The Director's Decision gave the NRC staff a mechanism to assist them in placing additional controls on spent fuel shipments to preclude the potential for recurrence of the noted incident. The inert fill gas precluded oxidation and particulate generation from any failed or damaged fuel assemblies. Canning of known and suspected failed or damaged spent fuel prevented release of any dispersible particulate that might be held in defective cladding. What the Director's Decision didn't provide was guidance on the level of clad defect that would qualify as failed or damaged fuel, or a standard for canning of qualifying fuel.

The exception to the casks prohibited from shipping failed fuel, the Model NLI-1/2 (Certificate Number 9010), provided one example of an acceptable way to meet the canning requirement, but was not necessarily useful for other existing designs. The secondary container of the NLI-1/2 is more robust than a can, but is not qualified as a containment vessel and does not have to be leak tested as one. However, the already tight containment cavities of other designs might not accommodate new inner secondary containers that would be comparable to that of the NLI-1/2.

Shortly after the Director's Decision was issued in April 1984, Transnuclear (TN) submitted a Certificate revision request for their Model TN-9 spent fuel cask to allow transport of spent fuel, which included some failed assemblies, from West Valley, New York to the Dresden Nuclear Plant in Morris, Illinois. The TN-9 carried up to seven BWR assemblies in fuel slots that had little room to spare. TN engineers concluded that space in the fuel slot was not sufficient to incorporate a fuel can that could be evacuated for backfilling with inert gas. The proposed revision would use a thin sleeve with a mesh bottom as a fuel can for the known failed fuel. Since TN knew the clean-up capabilities at the destination facility, they argued that they could specify the mesh size for the can to be compatible with those capabilities, and therefore, satisfy the intent of the Director's Decision. The NRC evidently agreed, and issued a letter revision that allowed TN to use the can for the one shipping campaign. This was not a general revision, and the certificate of compliance was not changed. Instead, the NRC issued a letter amendment, applicable only for the planned shipping campaign.

The NRC reports that there have not been many domestic shipments of commercial spent nuclear fuel since the Director's Decision was issued in April 1984 [5]. If there have not been many spent fuel shipments, there have been fewer, if any, failed or damaged spent fuel shipments. Therefore, experience with the use of the Director's Decision on failed and damaged fuel is sparse.

Recent events have brought the issue of failed and damaged spent fuel to the fore. One anticipated event is the opening and start of operations of a deep geological repository, which is scheduled to occur in 2010. Another is the use of dual-purpose canister systems for dry storage at reactor sites until a suitable central storage facility or repository becomes available. The dual-purpose canister is initially used for storage, which is not affected by the Director's Decision, but will later be used for transport of the spent fuel contents. If the fuel is being placed in these canisters, which are sealed for storage, it is desirable to know that any stored spent fuel assemblies containing failed or damaged rods can be transported away from storage facilities without repackaging.

RECENT NRC GUIDANCE ON DAMAGED FUEL

The NRC interim staff guidance on transport and storage of failed and damaged spent fuel, ISG-1, provides a brief definition of damaged fuel, canning requirements for storage or transport, special containment requirements for transport, and guidance how licensees can demonstrate fuel condition.

The brief definition of damaged fuel provided in the guidance document is very broad, and does little to clarify the meaning of damaged fuel. The definition given is: "Spent nuclear fuel with *known or suspected* cladding defects greater than a hairline crack or a pinhole leak." The definition applies to storage and transportation. The definition does not provide information on what constitutes a hairline crack or a pinhole leak.

The guidance provided on canning of damaged fuel from ISG-1 is as follows: "Damaged fuel, as defined in Item 1 above, should be canned for storage and transportation. The purpose of canning is to confine gross fuel particles to a known, subcritical volume during off-normal and accident conditions, and to facilitate handling and retrievability." The provision for canning damaged fuel applies to spent fuel storage and transportation.

In addition to the above guidance for canning, special guidance that applies to transport of damaged spent fuel is provided in ISG-1. "Spent fuel, with plutonium in excess of 20 curies per package, in the form of debris, particles, loose pellets, and fragmented rods or assemblies must be packaged in a separate inner container (second containment system) in accordance with 10 CFR 71.63(b)."

Finally, guidance on demonstrating the condition of the fuel, which applies to storage and transportation, is given. The guidance is provided as follows: "As proof that the fuel to be loaded is undamaged, the staff will accept, as a minimum, a review of the records to verify that the fuel is undamaged, followed by an external visual examination of the fuel assembly prior to loading for any obvious damage. For fuel assemblies where reactor records are not available, the level of proof will be evaluated on a case-by-case basis. The purpose of this demonstration is to provide reasonable assurance that the fuel is undamaged or that damaged fuel loaded in a storage or transportation cask is canned."

A DAMAGED FUEL STANDARD, ANSI N14.33

Discussion of the treatment of damaged SNF was introduced during the annual meeting of the ANSI N14 Committee in November 1998. The introductory discussion at the 1998 annual meeting was followed by a more detailed discussion and recommendation for development of an ANSI standard on damaged SNF during the next year's annual meeting in November 1999. On April 28, 2000, ANSI N14 approved initiation of the project titled, *Storage and Transport of Damaged Spent Nuclear Fuel*, designating the project N14.33. The project was officially initiated in May 2000, and an expected completion date of July 2002 was assigned.

A writing group (WG) was formed over the next several months. The work of the WG began in January 2000. The WG currently consists of nine individuals representing utilities, cask vendors, federal agencies, and an industry research and development organization. The individuals and their affiliations are presented in Table 1.

Table 1. Members of the ANSI N14.33 Writing Group

Name	Affiliation	Category
William Lake, Chair	U.S. Department of Energy	Federal Government
Arped Lengyel, Secretary	Idaho National Engineering and Environmental Laboratory	DOE Laboratory
Robert Burgoyne	Booz-Allen and Hamilton	DOE Contractor
Matthew Eyre	Exelon Nuclear	Utility Industry
Goeffrey Hornseth	U.S. Nuclear Regulatory Commission	Federal Government
Ray Lambert	Electric Power Research Institute	Industry R&D
Michael Mason	Transnuclear, Inc.	Cask Vendor
Paul Plante	Maine Yankee Atomic Company	Utility Industry
Brian Wakeman	Dominion Services	Utility Industry

In addition to the members listed in Table 1, the ANSI N14.33 WG is seeking additional participants. The first priority of this search is to increase the number of cask vendor participants.

The WG's general approach for developing the standard is to use the NRC guidance contained in Interim Staff Guidance, ISG-1, the Director's Decision, DD-84-9, and other applicable NRC guidance and regulations. In addition to these NRC products, results from ongoing discussions between NRC and the Nuclear Energy Institute (NEI) an industry organization, will be used.

As of August 2001, the WG has worked for eight months on the standards development activity. The WG started its tasks with an annotated outline and a series of brief discussion papers developed by individual group members for the WG to consider. The WG is currently completing the second draft of the standard, and expects to complete a draft standard for submittal to the ANSI N14 Committee by the assigned completion date of July 2002.

The ANSI N14.33 Standard, as is the custom for ANSI N14 standards, will consist of a main body of text, which includes the requirements of the standard, and appendixes, which contain useful information for users of the standard. The information contained in appendixes to ANSI standards may include such things as examples, explanations, and sample procedures.

The ANSI N14.33 standard will apply to storage and transport of light water reactor fuel from boiling water reactors (BWR) and pressurized water reactors (PWR). The scope of the draft standard and the preliminary titles of appendixes are provided here.

> "This standard defines terms related to dry storage and transport of damaged spent nuclear fuel. It establishes procedures for identifying and categorizing damaged fuel. The standard provides:
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> 1. dry storage and transport requirements for canning damaged fuel;
> 2. procedures for identifying source terms for certain levels of damaged fuel;
> 3. procedures for determining the need for double containment of damaged fuel for transport;
> 4. requirements for double containment, as needed; and
> 5. requirements for demonstrating spent nuclear fuel conditions."

The following six appendixes have been proposed by the WG:

1. Illustrative examples of damaged fuel.
2. Identification and classification of damaged fuel.
3. Examples of cans.
4. Examples of demonstrating SNF conditions.
5. Preparation of casks for storage and transport of damaged fuel.
6. Disposal considerations.

The standard will provide criteria and procedures for identifying and classifying damaged fuel. Requirements will also be given for handling and canning damaged spent fuel. Special procedures and precautions needed to drain, dry, and back-fill storage and transport casks used for damaged fuel will be included in the standard, along with ways to establish proof of spent fuel condition prior to storage or transport.

A major uncertainty in this standards development activity relates to the issue of double containment for certain transportation situations. The requirements of 10CFR71.63 specifies the need for double containment for transport of specific quantities of plutonium. The rule exempts fuel elements from the requirement. However, ISG-1 call for use of 10CFR71.63 for certain fuel damage conditions. The one historical case where NRC required such containment for damaged fuel is the Model 125B cask, which is approved for fuel debris from the TMI-2 reactor. The difficult task for the WG is to specify an approach for such damaged fuel, and to establish criteria to determine when the need for canning damaged fuel becomes a need for double containment.

To further complicate the matter, NRC may soon issue a proposed rule to eliminate the double containment requirements in 10CFR71.63 [6]. The WG has decided to develop special requirements for this level of damage. If the double containment requirements of 10CFR71.63 are not eliminated, the standards will reflect that.

Another challenging issue facing the WG is the matter of retrievability. This was not considered in the Director's Decision, DD-84-9, and only mentioned in ISG-1. The issue relates to damaged fuel assembly hardware that could impact such things as safety in handling, or indirectly affect storage and transport safety because of configuration uncertainties.

SUMMARY AND CONCLUSIONS

Although regulatory practices related to transport of damaged SNF have been in place for more than 15 years, the need to apply them has not. With the expectation of transporting fuel to a repository, and the use of dual-purpose transportable dry storage systems at reactors has raised the interest of utilities, shippers, repository developers, and regulators. In response to this need, NRC has issued interim staff guidance on storage and transport of damaged SNF.

The American National Standards Institute, N14 Committee has been following and assessing the need for a standard for damaged SNF since 1999. In May 2000, ANSI N14 initiated a project to develop such a standard, designating the project ANSI N14.33. A writing group was formed, and started development of the draft standard about January 2001. The draft standard is progressing on schedule, and a draft for submittal to the ANSI N14 Committee is anticipated by July 2002.

REFERENCES

[1] U.S. Nuclear Regulatory Commission, *Director's Decision Under 10 CFR §2.206*, DD-84-9, John G. Davis, Silver Spring, MD, April 13, 1984.

[2] U.S. Nuclear Regulatory Commission, Spent Fuel Project Office, Interim Staff Guidance, *ISG-1 Damaged Fuel*, Rockville, MD.

[3] U.S. Federal Register, Vol. 48, page 54550, U.S. Nuclear Regulatory Commission, December 5, 1983.

[4] U.S. Nuclear Regulatory Commission, *Potential Oxidation of UO_2 in Irradiated Fuel and Its Regulatory Implications*, Research Information Letter, RIL-139, March 5, 1984.

[5] U.S. Nuclear Regulatory Commission, *Public Information Circular for Shipments of Irradiated Reactor Fuel*, NUREG-0725, Rev. 13, October 1998.

[6] U.S. Federal Register, Vol. 66, page 44360, U.S. Nuclear Regulatory Commission, July 17, 2000.