TRANSPORTATION OF FAILED OR DAMAGED FOREIGN RESEARCH REACTOR SPENT NUCLEAR FUEL

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ABSTRACT

Since resuming the Foreign Research Reactor Spent Nuclear Fuel (FRR SNF) Acceptance Program in 1996, the Program has had to deal with difficult issues associated with the transportation of failed or damaged spent fuel. In several instances, problems with failed or damaged fuel have prevented the acceptance of the fuel at considerable cost to both the Department of Energy (DOE) and research reactor operators. In response to the problems faced by the Acceptance Program, DOE has undertaken significant steps to better define the spent fuel acceptance criteria. DOE has worked closely with the U.S. Nuclear Regulatory Commission to address failed or damaged research reactor spent fuel and to identify cask certificate issues which must be resolved by cask owners and foreign regulatory authorities.

The specific issues associated with the transport of Materials Testing Reactor (MTR)-type FRR SNF will be discussed. The information presented will include U.S. Nuclear Regulatory Commission regulatory issues, cask certificate issues, technical constraints, and lessons learned. Specific information will also be provided on the latest efforts to revise DOE's Appendix B, Transport Package (Cask) Acceptance Criteria. The information presented in this paper will be important to foreign research reactor operators, shippers, and cask vendors, so that appropriate amendments to the Certificate of Compliance for spent fuel casks can be submitted in a timely manner to facilitate the safe and scheduled transport of FRR SNF.

SUMMART

Since resuming the Foreign Research Reactor Spent Nuclear Fuel (FRR SNF) Acceptance Program in 1996, the Program has had to deal with difficult issues associated with the transportation of failed or damaged spent fuel. In several instances, problems with failed or damaged fuel have prevented the acceptance of the fuel at considerable cost to both the Department of Energy and research reactor operators. In response to the problems faced by the Program, DOE has taken significant steps to better define MTR-type FRR SNF characteristics that may be used to complete planning for shipping and storage. This information is important to foreign research reactor operators, shippers, and cask vendors, so that appropriate amendments to a cask's Certificate of Compliance and Certificate of Competent Authority for spent fuel casks can be submitted in a timely manner to facilitate the safe and scheduled transport of MTR-type FRR SNF.

INTRODUCTION

Beginning in the 1950s, as part of the "Atoms for Peace" program, the United States provided nuclear technology to foreign nations for peaceful applications in exchange for their promise to forego development of nuclear weapons. A major element of this program was the provision of research reactor technology and the highly enriched uranium (HEU) needed in the early years to fuel the research reactors. In the past, after irradiation in the research reactor, the spent nuclear fuel was returned to the United States so that the United States maintained control over disposition of the HEU that it provided to other nations. The United States accepted foreign research reactor spent nuclear fuel until the "Off-Site Fuels Policy" expired in 1988 for HEU fuel and 1992 for low enriched uranium (LEU) fuel.

On May 13, 1996, the U.S. Department *of* Energy issued a *Record of Decision on Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel* [1]. The goal of the long-term policy is to recover enriched uranium exported from the United States, while giving foreign research reactor (FRR) operators sufficient time to develop their own long-term solutions for storage and disposal of spent fuel. The spent nuclear fuel (SNF) accepted by the United States under this policy must be discharged from the research reactors by May 12, 2006 and returned to the U.S. by May 12, 2009.

Forty-one countries have U.S. origin enriched uranium and are eligible for shipment to the United States under the policy. The total inventory of eligible fuel contains approximately 17,000 MTR-type SNF assemblies and approximately 5,000 Training, Research, Isotope, General Atomic (TRIGA)-type SNF elements. The SNF will be packaged in shipping casks at the sites and transported to one of two DOE receiving sites. For MTR-type fuel, the receiving site will be the Savannah River Site (SRS) in Aiken, South Carolina. For TRIGA fuel, the receiving site will be the Idaho National Engineering and Environmental Laboratory (INEEL). All SNF will be transported dry in U.S. Nuclear Regulatory Commission (NRC) licensed or Department of Transportation (DOT) validated casks. The MTR-type SNF will be initially stored under water at existing wet storage facilities at SRS. The TRIGA SNF will be stored dry upon receipt at the MEL Irradiated Fuel Storage Facility.

Much of the FRR spent fuel which will be accepted by the DOE has been stored for long periods of time (10 to 30 years) in facilities not designed for long-term storage. The deterioration of some of the spent fuel in storage required that the DOE develop acceptance criteria for the transportation and storage of the spent fuel, especially in light of the numbers of assemblies to be accepted under the new policy.

Phase I

Initially, in response to the absence of clear regulatory guidance or technical standards for canning MTR-type fuel which has material conditions such as through-clad pitting, the Westinghouse Savannah River Company (WSRC) undertook an effort to develop standards by which MTR-type spent fuel would be judged for purposes of canning prior to transport. The task was based on a conservative approach in implementing definitions made in the *Environmental Impact Statement on a Proposed k4clear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel* (EIS) [2]. As stated in the EIS, the definition of "failed fuel" could be interpreted to require encapsulation of any spent fuel whose external cladding, in My 3ygy "has cracked, pitted, corroded or potentially allows the. leakage of radioactive material." As was the case in the development of the WSRC criteria, such a broad interpretation could result in encapsulation of spent fuel that would not otherwise require encapsulation in order to meet requirements for transportation or storage.

This conservative interpretation resulted in the original SRS acceptance and storage criteria specifying that no exposed fuel meat from any form of cladding penetration on a fuel plate was allowed.

In early 1997, these conservative criteria were applied to SNF at several research reactors. Several fuel assemblies did not meet these acceptance criteria. One of the assemblies identified as failed under these criteria was a CIEMAT-owned MTR-type fuel assembly in storage at Dounreay. The cask owner, the shipper, and relevant competent authorities agreed that the assembly could be shipped within all transportation requirements. Nevertheless, DOE decided, in light of the only existing criteria, that they could not accept the fuel assembly unless it was canned. The canning and. transport of this assembly in a subsequent shipment resulted in additional costs to DOE.

Phase H

As a result of the situation in Dounreay, DOE recognized that the transport and storage criteria being used could have a tremendous impact on transport costs and storage requirements with no health or safety benefits. In response, DOE undertook efforts to clarify the criteria for transportation and storage of research reactor SNF, including the definition of "failed fuel" for those purposes. The clarification was necessary in order to distinguish failed fuel for purposes of transportation and storage from the nuclear industry's interpretation of reactor failed fuel as fuel which is no longer acceptable for use in-the reactor. Fuel that is no longer suitable for use in a reactor may be perfectly suitable for safe transportation and storage.

Because the accepted nuclear industry definition of reactor "failed fuel" applies to the performance of fuel during reactor operation and implies release of fission products during reactor operation, reactor failed fuel was considered an inappropriate term to use in considering the acceptability of fuel for transportation and storage. A more appropriate approach to the problem would be to define "acceptability" with respect to SNF behavior under the environmental conditions present during transportation and storage. The definition of "acceptability" depends principally on three factors: (1) fuel condition, (2) transportation requirements (per DOT and NRC regulations), and (3) receipt and storage at SRS or INEEL. After holding a series of discussions and mock technical reviews, the two receiving sites, INEEL and SRS, developed new criteria for accepting spent nuclear fuel. The DOE Savannah River Operations Office's Appendix B, Transport Package (Cask) Acceptance Criteria, was subsequently revised for MTR-type SNF based on this criterion.

However, as subsequent shipments demonstrated, our initial efforts did not resolve this issue. While DOE resolved internal operational and procedural requirements, the acceptance criteria did not address cask certification issues, which would allow the shipment of failed or damaged SNF. Cask certificates were considered to be under the purview of the cask vendors and regulatory authorities including the U.S. Department of Transportation (DOT) and the U.S. Nuclear Regulatory Commission (NRC) within the United States. Many casks were represented to be certified to transport failed or damaged SNF with only minor certificate amendments, if an amendment was necessary at all. Therefore, DOE's acceptance criteria effort focused largely on potential canning requirements for interim storage at the DOE management sites and not transportation. The resulting requirements for MTR-type SNF specified the following [3]:

I . Physical Condition

All spent nuclear fuel shall be visually assessed prior to cask loading to identify damaged fuel that could result in breakage of the assembly during handling. Additionally, all spent nuclear fuel shall be individually handled during cask loading operations as a final check that each assembly is structurally sound.

a. The physical condition of the spent nuclear fuel must comply with all applicable Transport Package certificate requirements.
b. The spent nuclear fuel must be structurally sound such that it will not change shape during handling.
c The spent nuclear fuel must not be bent or deformed that could cause interference with a cask basket or cask insert surfaces.

2. Increase in radioactivity prescribed in Section C of this Appendix is within specification.
3. Any other potential material condition or operating history concern identified by the Customer in Section A-7 of this Appendix has been accepted for transport and storage by DOE.

In mid-1998, during the review of an application for a certificate of competent authority on a cask planned to ship damaged fuel, the cask safety analysis and cask certificate were determined to be incomplete to support a certificate allowing transport of damaged or failed SNF in the United States. Upon further review, the safety analyses of other casks were also identified as incomplete in this area.

This issue has had an immediate impact on implementation of the policy and most recently resulted in DOE's inability to transport SNF from Brazil and Venezuela. Canning was not feasible for this shipment since the casks were already staged at or near the reactor facilities.

Phase III

To address this issue involving the transport of damaged fuel, DOE has undertaken efforts to assist cask vendors in obtaining appropriate cask certification or validation for the shipment of failed or damaged MTR-type SNF under the DOE FRR SNF Acceptance Program**.** DOE, WSRC, and the U.S. Nuclear Regulatory Commission have been working together to develop a methodology that can be incorporated into safety analyses to address the issues associated with transport of damaged SNF with exposed fuel meat. This effort will result in a report to be issued by WSRC that will provide a technical basis for containment analysis of the transportation for damaged aluminum-based SNF [4]. Cask vendors, regulatory authorities that certify or validate casks, shippers of SNF, and other interested organizations will be invited to attend a presentation on the technical details of the report. The first presentation of this material is tentatively planned to be held in the United States in early November 1998. The targeted audience and other affected organizations will be notified of the presentation. However, other interested parties may also attend. Other presentations Will be announced based on the interest generated by key organizations.

The contents of this report will contain:

- a discussion on metallurgy of aluminum-based SNF;
- an overview of containment analysis of shipping casks including an example containment analysis;
- a discussion on the bases for inputs and assumptions for aluminum-based SNF to include
  - basis for damaged fuel fraction and exposed surface area,
  - basis for release of fines from exposed fuel meat,
  - gaseous and volatile species release characteristics of oxides on MTR-type SNF,
  - basis for gas and volatile species source term,
  - basis for crud source term, and;
- a discussion on the sensitivity of volumetric leakage rate at standard conditions to assumed fuel condition the areas of dependence on
  - fuel burnup,
  - number of assemblies,
  - decay time,
  - breached fuel fraction,
  - fines,
  - penetration depth,
  - fraction of surface area with through-clad penetration,
  - crud,
  - volatile species, and
  - gas.

The data in the WSRC report should be invaluable to cask vendors interested in transporting MTR-type SNF in the United States. The data is expected to provide the technical basis for containment analysis of aluminum-based SNF transport using United States recognized standards and methodology for conducting analytical calculations such as ANSI 14.5 and NUREG/CR-6487 which can be incorporated into the specific cask characteristics. The report's data will support evaluations identifying the bounding conditions in which failed or damaged SNF can be safely transported in each specific cask. These conditions can then be incorporated into cask safety analysis as appropriate and the cask's Certificate of Compliance or Certificate of Competent Authority may be appropriately amended.

CONCLUSION

The DOE FRR SNF Acceptance Program will continually face the challenges associated with the shipment of failed or damaged SNF. Cask vendors and other organizations involved with the shipment of MTR-type SNF must be sensitive to damaged fuel issues and take early action to address problems so that shipment delays and other related costs can be avoided. Interested parties are highly encouraged to attend presentations offered by DOE and to evaluate the assumptions, bases, and conclusions of the report, *Bases for Containment Analysis for Transportation of Aluminum-Based Spent Nuclear Fuel (Draft)* [4]. Stakeholders interested in the transportation of damaged spent fuel should take appropriate action to obtain cask certificate amendments by combining this information with each specific cask characteristics to enable the safe transport of failed or damaged MTR-type SNF to the United States.

REFERENCES

1. Record of Decision for the Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Nuclear Fuel. May 1996, U.S. Department of Energy.

2. DOE/EIS-0218F, February 1996. Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel.

3. Appendix B Agreement, Transport Package (Cask) Acceptance Criteria, Revision 8, March 1998.

4. N. C. Iyer, R. L. Sindelar, P. S. Blanton, and D. W. Vinson, "Bases for Containment Analysis of Transportation of Aluminum-Based Spent Nuclear Fuel," October 1998 DRAFT