U.S. DEPARTMENT OF ENERGY OPERATIONAL EXPERIENCE WITH SHIPMENTS OF FOREIGN RESEARCH REACTOR SPENT NUCLEAR FUEL

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Abstract

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

Since resuming the Foreign Research Reactor Spent Nuclear Fuel (FRR SNF) Acceptance Program in 1996, the DOE has successfully accepted shipments of spent fuel from Europe, South America, Australia, Canada, and Southeast Asia. For these shipments, trucks, trains, ships, and, in one case, an aircraft have been used to effect the shipments. Each shipment has proven to be unique in some aspect and the lessons learned from each of these shipments have been incorporated to make future shipments go more smoothly. However, challenges remain as shown by the recent shipment from South America in which DOE was unable to accept all of the spent fuel planned for the shipment.

The operational experience of the transport of FRR SNF will be discussed. The information presented will include transport logistics, regulatory issues, technical constraints, and lessons learned. Specific information will also be provided on research reactor operators responsibilities for joint shipments in which spent fuel from other countries is involved. As the Foreign Research Reactor Spent Fuel Acceptance Program moves into its third year, DOE has demonstrated that it can successfully accept FRR SNF on a regular basis. The continued success of the program depends upon the informed cooperation of all parties to the acceptance of this spent fuel. The information presented in this paper will be important to foreign research reactor operators and their host governments, shippers, cask vendors, and stakeholders to the movement of radioactive materials to and within the United States.

INTRODUCTION

Beginning in the 1950's, 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. Research reactors play a vital role in important medical, agricultural, and industrial applications. Nevertheless, the HEU initially used in the fuel elements for these reactors can also be used in nuclear weapons. 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.

To further reduce the danger of nuclear weapons proliferation, the United States in 1978 initiated the Reduced Enrichment for Research and Test Reactors (RERTR) program, which was aimed at reducing the use of HEU in civilian programs by promoting the conversion of research reactors from HEU fuel to low enriched uranium (LEU) fuel. From the beginning of the RERTR program, foreign research reactor operators made it clear that their willingness to convert their research reactors to LEU fuel was contingent upon the continued acceptance by DOE of their spent nuclear fuel for disposition in the United States. 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 LEU fuel.

In anticipation to resume the spent nuclear fuel acceptance policy in the United States, an environmental impact study was performed and an Environmental Impact Statement (EIS) was issued in February 1996. [1] 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 (ROD) [2] based on the bounding conditions of the EIS. An implementation strategy plan was subsequently issued to provide strategic guidance and major activities required to effectively implement the nuclear fuel acceptance policy. The goal of the spent nuclear fuel acceptance policy is to recover enriched uranium exported from the United States, while giving foreign research reactor operators sufficient time to develop their own long-term solutions for storage and disposal of spent nuclear fuel. The spent nuclear fuel accepted by DOE under the policy must be discharged from the research reactors by May 12, 2006 and returned to the U.S. by May 12, 2009.

Since resuming the foreign research reactor spent fuel acceptance program in 1996, DOE has successfully accepted shipments of spent fuel from Europe, South America, Australia, Canada, and Southeast Asia. For these shipments, trucks, trains, ships, and, in one case, an aircraft have been used to transport these transportation packages. Each shipment has proved to be unique in some aspect and the lessons learned from each of these shipments have been incorporated to make future shipments go more smoothly. The implementation of these shipments has required a concerted and coordinated effort between DOE, the foreign research reactor operators, and the various shippers. As the FRR SNF program moves into its third year, the continued success of the program depends upon the ability of DOE and research reactor operators to learn from past experiences and ensure that future shipments of spent fuel are safe, secure, and economic.

OPERATIONAL EXPERIENCE WITH SPENT FUEL SHIPMENTS

The experiences and lessons learned over the past two years have been categorized into the following groups:

- Scheduling
- Reactor Facility Equipment
- Transportation Logistics
- Contract Issues
- Security
- Technical Issues
- Public Relations
- Other Lessons Learned

Scheduling

Establishing and maintaining a schedule involving international shipments from several countries using different transport package types, and occasionally more than one ship, is very difficult. The DOE cannot control many of the variables associated with establishing a fixed schedule. However, through cooperation between all participants, costly schedule changes and delays can be minimized to ensure that all eligible reactor operators desiring to participate can return their eligible spent fuel. Good scheduling is especially important in order to maximize shipments early in the program to ensure that all material can be returned within the policy period. It is to the advantage of all participants to ship eligible material as early as possible. Early commitments to a schedule helps ensure that (1) a shipment is planned for a date convenient to the reactor facility; (2) a reactor can ship their fuel under the program; (3) reduce cost by providing opportunities to coordinate shipments with other reactors; and (4) return fuel before management fees increase.

The largest limiting factor in scheduling shipments is the availability of transportation packages or casks. There are a limited number of casks available to conduct these shipments. Additionally, the cask and its associated equipment must be compatible with a specific facility for loading. Casks must also be certified within the originating country, the United States, and any countries the loaded cask will transit. The DOE does not control cask utilization or certification by U.S. authorities, but does conduct advance planning based on prospective cask availability. Westinghouse Savannah River Company (WSRC) personnel at the receiving facilities at the Savannah River Site (SRS) are trained and equipped to unload each cask as quickly as possible so that the cask can be made available for future shipments. The DOE commits to unload casks at the rate of four per month, but frequently surpasses this expectation in the absence of facility equipment difficulty.

The DOE maintains basic information regarding eligible reactor operators and facilities, but does not maintain detailed information about the fuel or facility until a facility is targeted for shipment. Shipments of material may be better coordinated when detailed information is promptly provided to include a comprehensive Appendix A, Spent Nuclear Fuel Acceptance Criteria. An Appendix A is an appendix to the contract between the reactor operator and DOE-Savannah River in which the reactor operator provides detailed information regarding their spent nuclear fuel. (See definition under Contract Issues.)

DOE must also understand the reactor operator's shipping needs or desires. The DOE will work with any eligible reactor operator to meet special needs within the authorization of the EIS and ROD. Additionally, advance understanding of the reactor operator's shipping desires such as time of year, cask preferences, shipper preferences, plans for combining shipments, and other special considerations will assist in effective and efficient scheduling for the benefit of all participants. Cask preferences must also consider facility equipment and size issues that are identified in the following section.

Reactor Facility Equipment

For each nation designated as having "other than a high-income economy" and from which spent fuel will be accepted under the program, DOE, or its transportation services contractor, visits each qualifying research reactor facility in that country. The visits have several purposes which include, among others: (1) to discuss contractual and programmatic issues; (2) to conduct fuel inspections; and (3) to obtain information on facility equipment.

A specific area of concern that has caused delays in shipment schedules and substantial increases in overall transportation costs has been the inability of reactor facilities to support a shipment because of a specific cask size and weight. In many cases, the reactor facilities are decades old and have not had to support spent fuel cask loading operations in which casks weighing over 10 to 20 tons must be used. Even though, a reactor facility's overhead cranes may have been initially rated to handle cask weights up to these levels, the cranes are, in reality, unable to support the heavy weight of a shipping cask. In one case, the overhead crane broke down when the heavy load of a cask was placed on it, a much heavier load than the crane had handled since it was initially installed. The crane failure caused several days delay with substantial repair and ship demurrage charges. Verification of equipment operability under planned loads is critical to efficient loading operations.

In addition to weight issues, some reactor facilities are too small to load spent fuel in storage pools directly into the large shipping casks used for transport of spent fuel to the United States. To overcome this physical constraint, transfer casks must be designed or modified to fit the particular reactor facility dimensions. There is significant lead-time involved in designing and constructing/modifying, and certifying a transfer cask or shroud device and the need for such equipment must be identified early in the planning process to avoid negative impacts on schedule. Reactor operators, cask owners, and transporters must work together early in the planning process to avoid situations in which a cask is rented for a spent fuel movement, only to find that it is too heavy for facility cranes, too heavy for floor loading limits, or too tall for overhead clearances. Careful attention to these important, but occasionally overlooked details, can avoid costly delays.

Transportation Logistics

The transportation planning process undertaken by DOE for FRR SNF shipments is designed to minimize cost to participants, meet applicable transportation regulations, and mitigate concerns by regulators and other interested parties. Within the United States, transportation planning is conducted in an open forum with interested organizations. These organizations provide significant input into recommendations for needed actions and resolution of identified issues. The planning sessions for shipments to the Savannah River Site are coordinated by the Southern States Energy Board (SSEB) to ensure proper communication with all identified organizations. For example, the SSEB was essential in assisting in the resolution of a major concern by the state of South Carolina regarding the planned truck route for shipments from the terminal in Charleston to SRS.

The EIS analyzed the shipment of eight transportation packages on one oceangoing vessel. After publication of the EIS, the success of the program has resulted in the inventory of available spent fuel casks to increase. Consequently, DOE has reviewed the eight cask per ship "limit" and determined that up to sixteen casks may be transported on a single vessel, assuming that the appropriate activity limits are not exceeded for the INF class of vessel. Reactor operators and shippers working together with other reactor operators in nearby geographic areas can maximize the sixteen-cask-per-ship limit and therefore minimize the shipping cost to each participating reactor operator. Some ships transporting spent fuel from countries with high income economies have carried as few as four packages. To minimize these costs, early identification of shipping participants within nearby geographic regions is necessary to allow proper authorizations within each country. When making a port of call, packages on board as well as the package being shipped from the country's facility must be certified in that country and appropriate permits must be obtained.

During a multi vessel shipment, the first vessel to arrive at the entrance to the Charleston, South Carolina harbor must wait until the second vessel arrives. This can lead to demurrage charges as well as other logistical and scheduling problems if ship arrivals are not closely coordinated. During one shipment, one vessel moored off shore for ten days without sufficient fresh water. The *Record of Decision* that established the FRR SNF program requires that DOE minimize the number of spent fuel shipments to the United States. A single shipment could use multiple vessels that are off-loaded onto a single train for transit to SRS. Therefore, the oceangoing vessels must enter the Port of Charleston simultaneously and be sequentially off-loaded as a single evolution to classify the activity as one shipment. Once an arrival date is set for a shipment that uses two vessels, a vessel that does not arrive on time will cause the other vessel to stand by outside the port of entry until a new arrival date is established. The next authorized arrival date may not be the next calendar day after arrival of all vessels at the port entry. The new date will be established as soon as possible, but is primarily contingent on the port and terminal availability. Even though the reactor operator may experience additional charges to conduct a joint or combined shipment in these situations, the overall cost to the reactor operator should be significantly less for a joint shipment than if the reactor operator pursued a shipment dedicated only to fuel from one reactor.

Contract Issues

Just as DOE learns from past operational experiences and improves the transportation process, DOE is making important changes to the contracts between research reactor operators and the DOE receiving site. The latest revisions to the contract address two issues of importance. First, DOE is including a clause to clearly state that DOE can not accept any spent fuel after May 12, 2009. For research reactors wanting to operate until May 12, 2006 and then attempt to return their spent fuel, the impact of this clause should be considered in their internal discussions regarding reactor shutdown or conversion. Second, the fee policy has been revised to account for changes in a research reactor's host country's economic status. If the economic status of a country changes from an "other than high income economy" to a "high income economy," DOE will no longer financially support the shipment and all shipment costs and management fees will be borne by the research reactor after a specified period of adjustment.

In general, contracts between the reactor operator and DOE-Savannah River Operations Office (SR) should be finalized as early as possible once a reactor operator decides to participate in the FRR SNF program. The contract ensures that the reactor operator is an eligible participant and that all terms are identified and understood before any significant effort is taken toward implementing a shipment. Because the program supports the RERTR Program's objective to suspend use of HEU in research reactors, as a condition of the contract, the reactor operator must either already use LEU fuel, be permanently shut down, convert to the use of LEU fuel, or shut down the participating reactor. Further detail on research reactor eligibility requirements may be found in the EIS or ROD. Ideally, contract negotiations should be initiated at least one year in advance of the first desired shipment date with a goal of issuing an approved contract approximately nine months in advance.

The contract requires that all regulatory requirements be met for a shipment. Cask certifications must be valid in all involved countries, import and export permits obtained, specific advance notifications made to the proper authorities, and details of the shipment not released to the general public until 10 days after a shipment arrives at the destination in the United States. There have been instances in the past in which these security requirements were not met, primarily because of improper notification or coordination with regulatory authorities.

An Appendix A, Spent Nuclear Fuel Acceptance Criteria, and Appendix B, Transport Package (Cask) Acceptance Criteria, are included with the contract. Requirements contained within these documents have significantly changed since they were first issued on May 12, 1996. The changes usually benefit the reactor operator. Reactor operators and affected participants should ensure they obtain the latest version of these documents from DOE prior to initiating planning for each shipment.

Security

Although there have been no security related incidents with FRR SNF shipments other than notification issues, security remains a high priority due to the nature of the cargo and the sensitivities that accompany these types of shipments. Shipping dates are protected in accordance with the U.S. Nuclear Regulatory Commission (NRC) regulations and by contract between the reactor operator and DOE. For this reason, all organizations should coordinate any release of information with the appropriate DOE Public Affairs Officer who is responsible for knowing and implementing these requirements. Shipment information can only be shared with organizations with the need to know to carry out their function in support of the shipment. Under current U.S. regulations, the shipment cannot be announced publicly until ten days after the shipment arrives at SRS. Variances have been granted to publicly announce the shipment arrival at SRS immediately upon arrival. In one case, a release of information was inappropriately made to the news media by an organization unfamiliar with the regulation prior to shipment arrival.

Security plans are established for all legs of a shipment. For countries with "high income economies," the reactor operator is responsible for providing appropriate security for the entire duration of the shipment. The only exception to this responsibility is during the unloading at the terminal within the port of entry in the United States. Port security in the United States and vessel unloading support are provided by DOE. Nevertheless, the reactor operator, shipping agent, and DOE must work together to ensure security for all phases of the shipment.

For reactor operators in countries with "other than high income economies," the security of the shipment is a shared responsibility. Within the reactor operator's country, the reactor operator's local law enforcement is responsible within the country's jurisdictional capabilities. Any additional security requirements identified by a security assessment to support the security plan are provided by the DOE's Transportation Services Contractor and internal DOE security personnel. In one case, security concerns resulted in air transport of a spent fuel cask from the reactor facility to the country's port of export. Although air transport of a loaded cask is extremely rare, air transport was determined to be safer than exposure to the potential threats associated with a lengthy overland transit through isolated areas between the reactor and the port. The responsibility for security of the shipment after the material is loaded on the oceangoing vessel at the reactor operator's port is resolved during contract negotiations between the reactor operator and DOE. In general, the host country is responsible for security as long as the spent fuel is within their territorial limits. However, regardless of responsibility, the security assessment includes all segments of the transportation route from the reactor site to the DOE receiving site.

Technical Issues

There are several technical issues that have caused concern during the planning and implementation of shipments. Potential technical concerns should be raised as soon as possible to provide the best chance for resolution and to prevent shipment delays or non-acceptance of spent fuel planned for shipment.

In early 1997, problems with determining fuel conditions acceptable for shipment to and storage at SRS without encapsulation led DOE to assess the basis for canning requirements. Initially, spent fuel conditions for transport and storage were not well defined for failed or damaged fuel. A strict interpretation of failed fuel was established based on studies conducted at SRS and other reactor facilities. This initial "canning" criteria led to one MTR-assembly stored at the United Kingdom Atomic Energy Agency's Dounreay facility being encapsulated prior to shipment because of nodules indicating through clad penetrations that expose fuel meat to the cask environment. Further evaluation of the physical behavior of metallic fuels led to a revision to the requirements clarifying when encapsulation is necessary. Fuel condition must now meet cask certificate requirements as well as requirements specified in the most current revision of the Appendix B.

However, there are insufficient numbers of casks that are certified in the U.S. to ship failed or damaged fuel. To address this issue, DOE undertook efforts to assist cask vendors in obtaining appropriate certifications for the shipment of failed or damaged MTR-type SNF. This effort resulted in a report to be issued by the WSRC that provides a technical basis for containment analysis of the transportation of damaged aluminum-based fuel. [3] It is anticipated that cask vendors will use the WSRC technical data, incorporate their specific cask data, and apply and obtain amendments to their cask certificates. The first submittal of this new technical data and approach is tentatively planned for early November 1998.

Additionally, early issuance of a comprehensive Appendix A and verification of the cask's U.S. Certificate of Compliance is essential for DOE to complete all prerequisites to issue an Authorization to Ship letter. This letter acknowledges receipt of an acceptable Appendix A(s), specifies that DOE has made all preparations to accept the material, and provides authorization to ship the material. Although a reactor operator may chose to "load at risk," the reactor operator cannot allow the material to depart the reactor site until this letter is received by facsimile. Any activity conducted prior to receipt of this letter is a risk taken by the reactor operator. Good coordination and cooperation by the reactor operator, Shipper of Record, and DOE usually ensures that the "Authorization to Ship" is issued prior to its need.

Casks are required to be loaded into standard 20 foot ISO containers. Flat racks or skids that may be handled in the same manner as a standard 20 foot ISO container may also be used. However, the cask should be covered in some manner such as the tarps used by the Japanese for their cask shipments.

Reactor operators, contractors, and vendors should ensure that any special cask handling and fuel handling tools and equipment are shipped with the spent fuel cask and that all required shipping papers are readily available. In several shipments, special shipments of cask handling tools have been required because the tools were not shipped with the casks. The resultant delays are costly and can impact the next critical path activity leading to future shipment delays and increased costs.

Public Relations

Public relations is an important part of the successful implementation of the program to return U.S. origin spent nuclear fuel to the United States. The DOE has made a concerted effort to inform and involve the public and to obtain public support for the implementation of this policy.

The successful first shipment of FRR SNF through San Francisco Bay in California, in July 1998 involved enormous public relation efforts. After the shipment was successfully completed with little in the way of protests, the follow-on press coverage was favorable. The DOE continues to work with members of the public and their representatives when they raise issues associated with this program.

Reactor operators have similar, but uniquely different issues regarding their effort to ship the fuel out of their country. As one may imagine, depending on the attitude of the general population as well as special interest groups, each reactor operator must proceed in accordance with their country's acceptance of the shipment of this material through their country and the transfer of spent nuclear fuel to the United States. The DOE can assist in public relations activities as requested by the reactor operator.

Conclusion

To date, every shipment has had contractual, technical and logistical issues which required resolution prior to shipment. Early identification of issues will allow DOE-SR, DOE contractors, and shipping agents, as appropriate, to mitigate any potential obstructions to making a cost-effective and timely shipment. "Lessons Learned" reviews are conducted by DOE with participating United States organizations after each shipment so that future shipments can be conducted in the safest and most effective manner possible. Any issue raised is documented, evaluated, and tracked to closure. Through this process, DOE hopes to improve the efficiency of FRR SNF shipments into the United States.

REFERENCES

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[3] N.C. Iyer, et al., "Bases for Containment Analysis of Transportation of Aluminum-Based Spent Nuclear Fuel," October 1998.