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ABSTRACT

The U.S. Department of Energy announced its Record of Decision on January 14, 1997, to embark on a dual-track approach for disposition of surplus weapons-usable plutonium using immobilization in glass or ceramics and burning plutonium as mixed-oxide (MOX) fuel in reactors. In support of the MOX fuel alternative, Oak Ridge National Laboratory initiated development of conceptual designs for a new package for transporting fresh (unirradiated) MOX fuel assemblies between the MOX fabrication facility and existing commercial light-water reactors in the United States. This paper summarizes progress made in development of new MOX transport package conceptual designs. The development effort has included documentation of programmatic and technical requirements for the new package and development and analysis of conceptual designs that satisfy these requirements.

INTRODUCTION

Oak Ridge National Laboratory (ORNL), under sponsorship of the U.S. Department of Energy's (DOE's) Office of Fissile Materials Disposition, initiated development of preliminary concepts for fresh mixed-oxide (MOX) fuel transport packages at the beginning of FY 1997. The need for developing a new package for fresh MOX fuel assemblies was based on three established facts. First, preliminary investigation determined that, despite the existence of a number of package designs for fresh MOX fuel, only one package design was certified in the United States. In addition, as that package design was not certified to the most recent United States transportation regulations, no additional packagings could be manufactured without significant updating and reevaluation of the safety documentation for that existing package design. Second, since specific reactors had not been selected to burn the weapons-grade MOX fuel, it was unlikely that any of the existing MOX package designs would be completely adequate to accommodate the as-yet undefined MOX fuel assembly designs, especially since the fuel assemblies would be composed of MOX fuel resulting from weapons-grade plutonium. And third, since MOX fuel is classified as Category I Special Nuclear Material (SNM), DOE has planned to use its Transportation Safeguards System (TSS) and fleet of safe, secure trailers (SSTs), armored tractors, and escort vehicles to provide security during transport from the MOX fabrication facility to the commercial light-water reactors (LWRs). Based on the possibility of shipping up to 1800 pressurized-water reactor (PWR) or 9300 boiling-water reactor (BWR) fuel assemblies over a 15-year campaign, a new, higher capacity, fresh MOX fuel package design could result in savings of $12M to $25M in transportation costs, depending on the distance between the MOX fabrication facility and the mission reactors.

BACKGROUND

Following the January 14, 1997, Record of Decision (ROD) that recommended MOX as part of a dual-track approach

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for the disposition of surplus weapons-grade plutonium, DOE began preparation of a strategy[1] for deployment of MOX fabrication and reactor irradiation services using the experience of a consortium of nuclear fuel vendors and commercial nuclear utilities to assist in accomplishing the mission. To support this activity, ORNL summarized the transportation and packaging issues in a report[2] that described the planned shipment of fresh MOX fuel assemblies from the MOX fabrication facility to one or more commercial LWRs. This report describes a concept of operations that characterizes the interfaces between DOE's MOX fuel transportation system, the MOX fabrication facility, and the mission nuclear power plants. The transportation system includes (1) DOE's SST vehicles and system of transportation safeguards, (2) associated transportation physical security operations, (3) the fresh MOX fuel transport package, and (4) the consortium's fuel-handling operations and storage facilities.

When compared with low-enriched uranium (LEU) reactor fuels, the most noteworthy differences in the transportation and packaging of MOX fuel are related to the type of package and the need for additional security during transport. MOX fuel, due to the presence of plutonium, must be transported in Type BF packages, while LEU fuel is transported in Type AF packages. Type BF packages must satisfy a rigorous set of performance tests to simulate the environments typical of transportation accidents, including conditions of impact, puncture, temperature, and water immersion.

Because of the quantity of plutonium in each shipment, additional security is required. MOX is classified as Category I SNM. In the United States, DOE maintains the only active capability that meets the rigorous security requirements needed for transport of Category I SNM. This capability, known as TSS, is operated by DOE's Albuquerque Operations Office, Transportation Safeguards Division (TSD). TSD operates a fleet of SSTs, armored tractors, escorts, and escort vehicles and a state-of-the-art tracking and communications system to maintain constant monitoring and contact with in-transit shipments of SNM. SST, from outward appearances, looks like every other semitrailer on the road today. That is where the similarity ends, however, since SST provides significant protection for the material being transported by use of ballistic protection, crash and thermal resistance, and other deterrent systems. Unlike LEU fuel shipments, which do not require as much physical security and are generally transported using Type AF packages loaded and secured to open (flat-bed) trailers, MOX fuel would need to be transported by SST.

SST imposes two additional constraints on the MOX fuel package. First, the payload of SST (to comply with U.S. vehicle weight regulations) is limited to about 16,500 lb. Second, use of a covered trailer may impose additional handling complexity at the reactor. The reactor may need to make some modifications to accommodate the loading and unloading of the MOX packages through the rear door of SST (rather than the relatively simple unloading of LEU fuel packages using a crane to lift the packages off the truck). In addition, the fuel-handling area at the reactor and the facility operations may need to be modified to accommodate the presence of MOX fuel, which requires a higher degree of physical security than LEU fuel.

PACKAGE DESIGN REQUIREMENTS

To ensure timely availability of necessary packagings to meet the disposition mission schedule, ORNL began development of design concepts for new MOX fuel transport packages in FY 1997. As a first step in the package design process, ORNL developed a set of design goals and requirements for the new package. These requirements, broken into programmatic and technical groupings, were documented in a technical report.[3] This report also describes the package system, including a general description of the package components, package contents, operational features, interfaces, and packaging procedures.

Programmatic Requirements. Programmatic requirements established for the new package design specify that the package shall be (1) compatible with, and efficiently use, the available payload capacity of the SST; (2) certified by the Nuclear Regulatory Commission (NRC) as a Type B(U)F package in accordance with 10 CFR Part 71; and (3) operationally compatible with the MOX fuel fabrication and reactor facilities in which it is used.

The use of SST, as specified in the first programmatic requirement, is imposed because the fresh MOX fuel is classified as Category I material [by NRC or the International Atomic Energy Agency (IAEA)] and requires the highest levels of physical protection. The only currently available capability for providing Category I transportation security resides with DOE, which, through its TSD in Albuquerque, operates a shipment tracking/courier system that includes SSTs.

The second requirement, that the package is certified by NRC, is imposed for two reasons. First, it provides a consistency in regulatory oversight because both the MOX fabrication plant and the reactors will be NRC licensed. Second, by using certified Type B(U)F packages for the shipment of Type B quantities of material, operational requirements for SST are more easily met.

The third requirement was established to minimize the need for facility modifications and to ensure that the facilities in which the package will be used can handle receipt of the fresh MOX fuel. As an example of minimizing potential design or operational changes to the reactor, the package design (and operational considerations) should be engineered to both reduce the handling time needed for packaging operations (and thus minimize personnel doses) as well as to mitigate the consequences of postulated fuel-handling accidents (e.g., by reducing the maximum lift height of the fuel during handling).

Technical Design Requirements. In addition to the programmatic requirements, the package design must meet a number of technical requirements so that the package design can both (1) accommodate the proposed contents (fresh MOX fuel assemblies) and (2) successfully be certified as a Type B(U)F package by NRC.

The technical design requirements for the package fall into eight different categories:

1. General design requirements
2. Package design condition requirements
3. Structural design criteria
4. Nuclear design criteria
5. Operational and transportation interface requirements
6. In-service inspection/maintenance requirements
7. Manufacturing requirements
8. Quality assurance requirements

As appendices to the requirements document, ORNL compiled data on a number of topics to support the package design effort. Appendix A of the requirements document included a compilation of fuel assembly dimensional characteristics of all the fuel in use at U.S. reactors. These data allowed the design team to establish the initial design envelope for the package. Appendix B provided a summary of the SST transport vehicle, including interior dimensions and payload capacity data.

Appendix C provided a summary of MOX fuel-handling operations that would be expected at a typical commercial nuclear power reactor, based on use of a new MOX fuel package and SST as the conveyance that would transport the package to the reactor. Appendix D provided a summary of characteristics of other existing MOX fuel packages. The most significant conclusion from these data was that for any of the packages identified, only a single package could be accommodated in SST. Also, all the PWR package designs could accommodate two assemblies per package.

Appendix E described the NRC, DOE, and IAEA safeguards categories for fresh MOX fuel. Appendix F presented some very preliminary design concepts. These concepts were evaluated, as a first-order proof-of-principle effort, to determine if the design goals were credible.

Appendices G, H, and I provided some additional background information about the MOX fuel mission, international transportation regulations, and package testing requirements for certification.

PACKAGE CONCEPTUAL DESIGNS

Using the initial concepts developed for the requirements document as a starting point, the ORNL design team settled on two fundamental design concepts for further evaluation and refinement: the end-loading concept and the double-strongback concept. The end-loading concept has some similarities to spent fuel packages in terms of their orientation during loading and unloading operations. By contrast, the double-strongback concept is most similar to the other fresh fuel packages currently used for LEU reactor fuel assemblies. Based on the information collected during preparation of the package design requirements document, a design envelope was established to accommodate either PWR or BWR fuel assemblies. Table 1 summarizes the design envelope.

Table 1. MOX Fuel Transport Package Design Envelope

	PWR	BWR
Assemblies per package	4	8
Assembly length, in.	178.3	176.2
Assembly width, in.	8.54	5.52
Maximum assembly weight, lb	1505	687
Maximum total payload, lb	6020	5500

The design envelope encompasses essentially all of the BWR fuel assemblies and about 99% of all PWR fuel assemblies in the United States, with the exception of the South Texas Project PWR reactors that have 199-in.-long fuel assemblies. The package conceptual designs are documented in Ref. 4.

End-Loading Concept. The end-loading concept was designed to make the seal for the package closure as small as possible. Figure 1 shows a PWR version of the end-loading concept, capable of holding four fresh MOX fuel assemblies. The BWR version is similar to the PWR version and is capable of holding eight fresh MOX fuel assemblies. The end-loading concept also has the potential added benefit of reducing the amount of time and number of personnel needed during loading and unloading operations.

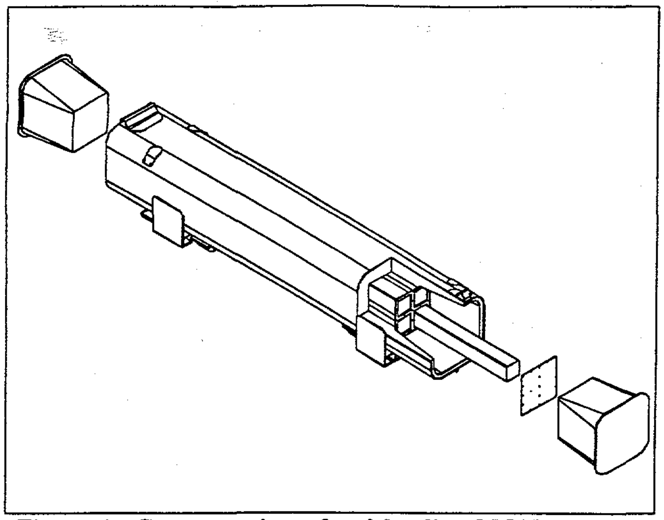

Figure 1. Cutaway view of end-loading MOX package concept for PWR fuel

One of the key design challenges has been trying to achieve a maximum payload capacity while minimizing the gross package weight. The gross package weight is limited by the payload capacity of the conveyance, which will be DOE's SST. Another concern the design team addressed was to provide sufficient criticality safety control within the constraining requirement of package gross weight.

The method chosen for criticality control within the package (under both normal and accident conditions) was to use 3/16-in.-thick B_4C neutron absorber plates positioned along the fuel assembly tubes, separated by a 1-in. gap between each tube/absorber plate compartment, as shown in Fig. 2. The 1-in. gap acts as a neutron flux trap if it becomes filled with water during a severe accident. The flooded condition is considered the "most reactive" configuration in terms of criticality safety. To simulate possible severe accident conditions, the 1-in. gap was assumed to be negated by the impact and crushing forces. In this case, the absorber plates maintain the k_{eff} at less than 0.95 despite the lack of spacing that eliminates the flux trap. Parametric evaluation of criticality safety was also performed by variation of (1) basket flooding, (2) absorber plate thickness, and (3) infiltration of water into the impact absorbing foam region.

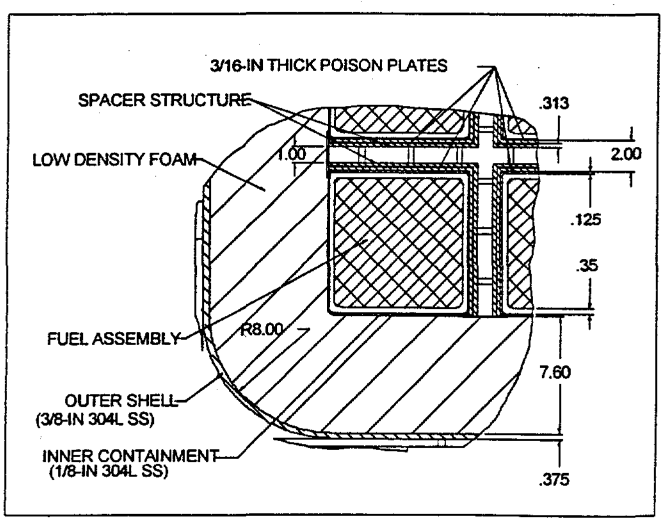

Figure 2. Detail view of PWR MOX package

In addition to the criticality safety evaluations of the package design, preliminary calculations of the external radiation dose rate and response to the puncture test conditions were performed to ensure that the design concept could meet these requirements. The dose rate calculations were performed to determine the dose rate external to the package in compliance with the transportation regulations. If the dose rates exceed regulatory limits, additional shielding material (and weight) must be added to the package to reduce the dose rate. The puncture test was simulated to determine if the initial assumption of an outer skin thickness of 3/8-in. stainless steel was sufficient to withstand a 40-in. drop onto a 6-in.-diam steel spike. The results showed that the package overpack deforms about 5 in., but the spike did not penetrate the outer shell to expose the impact-resistant foam.

Double-Strongback Concept. The double-strongback concept provides a package design that was most similar (in terms of handling) to the fresh fuel packages currently used at commercial nuclear reactors in the United States. The double-strongback concept should minimize the impact on the nuclear utility, in terms of the need for additional equipment, changes to procedures, and additional safety analyses. Many other LEU and MOX fresh fuel packages utilize a strongback contained within a protective overpack. This new concept includes a completely sealed inner box (containment volume) that contains two separate strongbacks that can be raised to a vertical orientation to accommodate loading or unloading of the MOX fuel assemblies. Figure 3 shows the double-strongback concept, with the strongbacks elevated to vertical orientation for unloading.

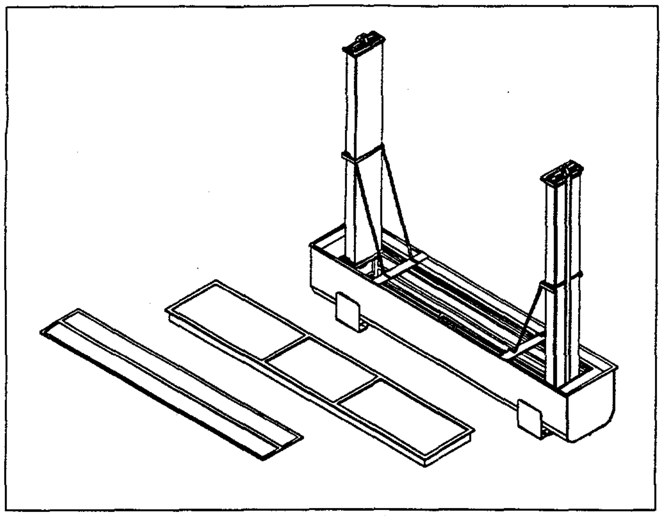

Figure 3. Double-strongback MOX package concept for PWR fuel (ready for unloading)

Figure 4 shows a cutaway view of the double-strongback concept. The containment volume cover and the inner shell cover are removed for loading and unloading operations. The containment volume structure is suspended and supported by low-density foam (6 lb/ft^3) within the outer shell. The low-density foam, which supports the containment volume during normal operations, is also designed to absorb impact energy and prevent rupture of the outer shell and containment volume during severe accident conditions.

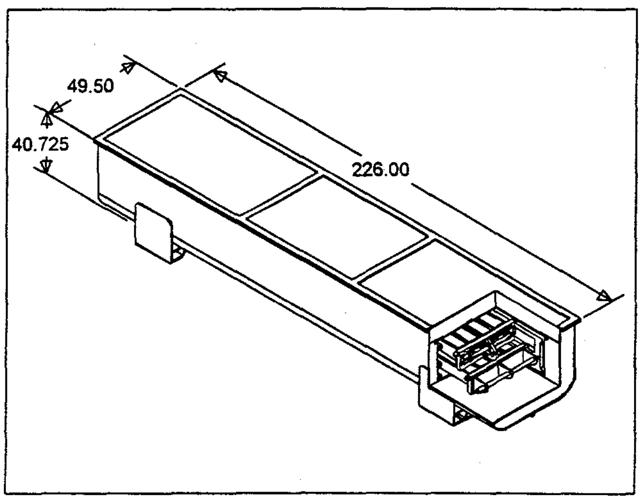

Figure 4. Cutaway view of double-strongback MOX package concept for PWR fuel

Figure 5 shows a cross-sectional view of the double-strongback concept. The package would rest on a support structure (feet) of the package, except during loading and unloading. Because the SST is a covered trailer, packages must be handled through the rear doors. To simplify the loading process, the support structure of the package includes lightweight removable wheels and a hydraulic jack system to elevate the package during installation and removal of the wheel assembly.

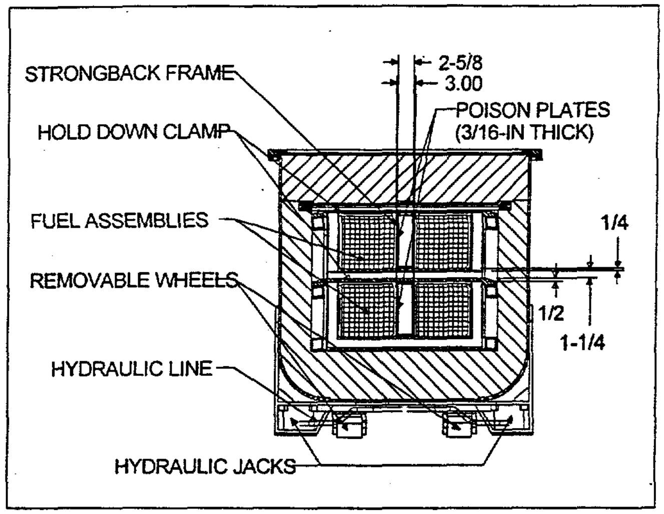

Figure 5. Cross-sectional view of the MOX double-strongback package concept for PWR fuel

Figure 6 shows a detail view of the double-strongback package concept. The location of gaskets and neutron absorber (poison) plates, and the relative location of the upper and lower strongbacks, can be seen from this view.

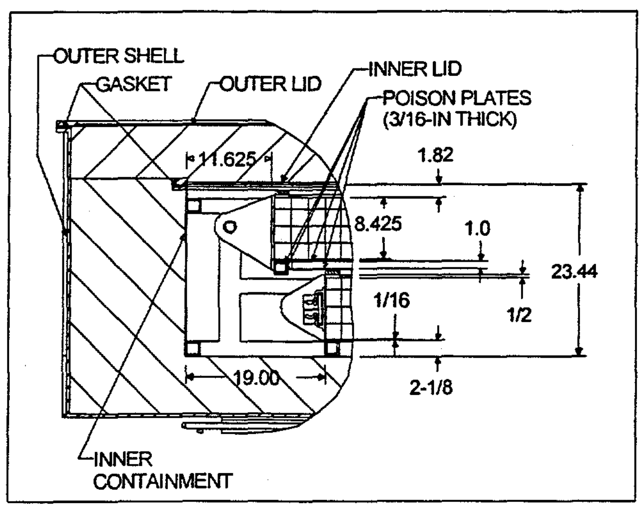

Figure 6. Detail view of PWR double-strongback MOX fuel package

SUMMARY

ORNL has completed preliminary design of two different concepts for fresh MOX fuel transport packages. Supporting the design effort, ORNL has documented the design requirements for the new package in a technical report. Both preliminary concepts appear to offer the possibility of increasing the number of MOX assemblies transported per shipment by as much as a factor of two when compared with existing U.S. or foreign MOX packages. Formal design of the new MOX package is ready to begin to meet the needs of the Fissile Materials Disposition Program. Safety analyses of the package design will support certification of the new MOX package by NRC.

REFERENCES

1. *Program Acquisition Strategy for Obtaining Mixed-Oxide Fuel Fabrication and Reactor Irradiation Services*, U.S. Department of Energy, July 17, 1997.
2. S. B. Ludwig, R. E. Best, S. P. Schmid, and D. E. Welch, *Transportation and Packaging Issues Involving the Disposition of Surplus Plutonium as MOX Fuel in Commercial LWRs*, ORNL/TM-13427, August 1997.
3. S. B. Ludwig, R. D. Michelhaugh, R. B. Pope, L. B. Shappert, B. H. Singletary, S. M. Chae, C. V. Parks, B. L. Broadhead, S. P. Schmid, and C. G. Cowart, *Programmatic and Technical Requirements for the FMDP Fresh MOX Fuel Transport Package*, ORNL/TM-13526, December 1997.
4. S. B. Ludwig, R. D. Michelhaugh, L. B. Shappert, S. M. Chae, and J. S. Tang, *Revised Conceptual Designs for the FMDP MOX Fresh Fuel Transport Package*, ORNL/TM-13574, March 1998.