Spent Fuel Shipping Cask Development Status*

EGG-M--88360

DE90 009761

K.H. Henry[1] and W.C. Lattin[2]

[1]Idaho National Engineering Laboratory,
EG&G Idaho, Inc., Idaho Falls, ID, and

[2]U.S. Department of Energy, Idaho
Operations Office, Idaho Falls, ID

INTRODUCTION

The Nuclear Waste Policy Act of 1982 (NWPA) authorized the U.S. Department of Energy (DOE) to establish a national system for the disposal of spent nuclear fuel and high-level radioactive waste from commercial power generation, and established the Office of Civilian Radioactive Waste Management (OCRWM) within the DOE-Headquarters (DOE-HQ) to carry out these duties. A 1985 presidential decision added the disposal of high-level radioactive waste generated by defense programs to the national disposal system. A primary element of the disposal program is the development and operation of a transportation system to move the waste from its present locations to the facilities that will be included in the waste management system. The primary type of disposal facility to be established is a geologic repository; a Monitored Retrievable Storage (MRS) facility may also be included as an intermediate step in the nuclear waste disposal process. This paper focuses on the progress and status of one facet of the transportation program--the development of a family of shipping casks for transporting spent fuel from nuclear power reactor sites to the repository or MRS facility.

BACKGROUND

The NWPA requires that the DOE use private industry to the fullest extent possible in developing a transportation system. Therefore, the DOE is relying heavily upon contracts with private sector companies to develop equipment and provide services for the future transportation system. In accordance with the intent of the NWPA, the DOE is also consulting with, and soliciting comments from, the private sector (e.g., private industry, State and local governments, Indian Tribes, and the public at large) in planning and policy development. The 1987

*Work supported by the U.S. Department of Energy, Office of Civilian Radioactive Waste Management, under Contract No. DE-AC07-76ID01570.

amendment to the Nuclear Waste Policy Act requires that any cask used by DOE/OCRWM to transport radioactive waste must have a certificate of compliance from the Nuclear Regulatory Commission.

Cask Acquisition Strategies

The transportation systems acquisition task is divided into two phases. Phase I covers the development and acquisition of prototype casks that will be used to ship spent fuel and high-level waste to or between Federal facilities. The DOE will develop a transportation fleet and implement transportation operations during Phase II.

Phase I of the transportation systems acquisition task includes four cask development initiatives. Initiative 1 covers the development of spent fuel casks to accommodate intact fuel assemblies or consolidated fuel rods. These casks will be used to ship 75 to 85 percent of the spent fuel from commercial nuclear power reactors to an MRS facility or repository. These "from-reactor" casks are the primary focus of this paper. If an MRS facility is approved by Congress, a highly efficient rail shipping cask will be developed under Initiative 2 for shipments from the MRS facility to the repository. This MRS-to-repository cask will be tailored to the unique cask handling capabilities at these two Federal facilities and the spent fuel processing and containerization options selected for the MRS facility. Initiative 3 will cover the development of one or more "specialty" casks for: (a) limited-quantity spent fuel that cannot be readily accommodated in Initiative 1 casks, and (b) miscellaneous nonfuel reactor waste materials requiring repository disposal. A rail cask for defense high-level waste will be developed under Initiative 4, in accordance with a 1986 memorandum of agreement between the DOE Office of Defense Programs and the OCRWM. New cask development under Initiatives 2 through 4 will be contingent upon a reaffirmation that modification of existing cask designs (e.g., Initiative 1 cask designs) would not provide viable alternatives.

Organizational Responsibilities

Responsibility for transportation systems and technology development has been assigned to the DOE-Idaho Operations Office (DOE-ID) by the OCRWM. This responsibility includes cask engineering development, development of associated transportation system hardware and cask handling methods, cask certification by the Nuclear Regulatory Commission, prototype testing, and associated technology development. The composite of these activities is referred to as the Cask Systems Development Program (CSDP). The primary contractor organizations participating in the CSDP under DOE-ID direction are EG&G Idaho, Sandia National Laboratories, and several cask development contractors selected from private industry.

EG&G Idaho provides general support services for the CSDP. EG&G Idaho also performs a strong technical liaison role with the cask development contractors, conducts generic technical studies related to cask systems design, and supports DOE-ID in the implementation of the quality management program.

Sandia National Laboratories (SNL) serves as the CSDP technology development laboratory, provides technical assistance, and addresses regulatory and technical issues that apply generically to the overall CSDP. Some of SNL's current activities are identified later in this paper.

Cask development contractors, selected from private industry, perform the actual cask design and development work. These contractors are responsible for the engineering, design, fabrication, certification, engineering testing, design verification testing, acceptance testing, and inspection services for prototype casks.

DEVELOPMENT OF FROM-REACTOR CASKS

Previous transportation cost and risk studies have shown that development of a new generation of shipping casks is warranted for transporting spent fuel from commercial nuclear power reactors to a repository or MRS facility. Several types of spent fuel shipping casks, both truck and rail, already exist and have been used successfully for many years. However, these casks were initially designed for transporting relatively short-cooled spent fuel (e.g., 150 days following discharge from the reactor) to a nuclear fuel reprocessing plant. Most of the spent fuel in storage at commercial nuclear power plant sites will be aged ten years or more prior to shipment to a Federal storage or disposal facility. Therefore significantly increased cask payloads (by a factor of three or more) are achievable, within the same radiation and thermal limits, by designing casks for the higher-aged fuel. Maximizing cask payloads will result in reduced numbers of shipments, and corresponding reductions in transportation costs and in the public and occupational risks associated with spent fuel transportation.

In addition to maximizing cask payload, there are several other important objectives in developing the new generation of spent fuel shipping casks. Since the Federal receiving facilities will have high throughput rates, maintaining low cask turnaround times and occupational radiation exposures will receive increased emphasis; these factors are also important to reactor site personnel. Therefore, innovative cask designs are encouraged in order to achieve more efficient and safer cask handling operations. Standardization of the physical interfaces between the casks and the shipping and receiving facilities will also facilitate these operations.

The request for proposals (RFP) for Initiative 1 (from-reactor) cask development was issued in July 1986. The DOE procurement strategy is to award more than one contract for each cask type. The purposes of this strategy are to diversify cask sources, provide multiple options for the cask fleet composition, and mitigate the potential adverse impacts of removing a single cask design from service.

In June 1987, two contractors were selected for legal-weight truck cask development [General Atomics (GA) and Westinghouse], and three contractors were selected for rail/barge cask development [Babcock and Wilcox (B&W), Nuclear Assurance Corporation (NAC), and Nuclear Packaging Corporation (NuPac)]. All five contracts were in place by July 1988, and the cask contractors are currently nearing completion of their preliminary designs.

Cask System Design Requirements and Guidelines

Cask development work under this program is not limited to casks, but instead covers cask systems. A cask system consists of: (a) the cask body, (b) a transport system (truck trailer or railroad car; barge design is excluded), (c) closure heads, (d) internal fuel support structures (basket, sleeves, and spacers), and (e) ancillary equipment. Ancillary equipment includes impact limiters, protective enclosures, lifting and tiedown devices, special tools, spare parts, and fixtures for cask draining, drying, filling with inert gas, and testing. Cask system development includes analysis, design, testing, certification, prototype fabrication, and thorough documentation.

The RFP for from-reactor casks included a statement of work, cask physical performance specifications, and cask interface guidelines. This information has since been incorporated into the cask development contracts. The cask physical performance specifications are divided into three categories, which are summarized as follows:

- **Baseline Requirements** -- Cask designs shall meet all applicable regulations and must receive a certificate of compliance from the NRC. Transporter designs must be in accordance with U.S. Department of Transportation and Association of American Railroad rules and regulations. All cask development activities shall be conducted under quality assurance programs that meet the requirements of 10 CFR 71 Subpart H and the ANSI/ASME quality assurance requirements of NQA-1.

- **ALARA and System Optimization Requirements** -- Cask designs shall maximize payload to the extent possible while remaining in compliance with other requirements and constraints. Capability to perform all cask handling operations by contact (i.e., "hands on"), remote, or remote-automated techniques shall be maintained. Casks and ancillary equipment shall be designed in accordance with as-low-as-reasonably-achievable (ALARA) radiation exposure principles on a total system basis. Cask turnaround times at receiving facilities shall not exceed 8 hours for truck casks and 12 hours for rail casks; corresponding limits at reactor sites are 12 hours (truck) and 18 hours (rail). Cask system components shall be designed to limit surface contamination and to facilitate decontamination. Handling and operational interfaces shall be standardized for all casks in a given weight class. Intermodal transfer capability (e.g., transfer from truck to rail) shall be included in all cask designs.

- **Additional Design and Development Requirements** -- Critical structural components shall undergo design verification testing; cask prototypes shall successfully complete acceptance and performance evaluation testing. Cask containment structural materials must meet consensus code requirements or be supported by independently verified test data. Casks shall be compatible with either underwater or dry (hot cell) loading and unloading methods. Where practical, casks shall be capable of accommodating special-case waste forms (e.g., failed fuel, hardware, etc.). Cask design life shall be 25 years, and transporter design life shall be 1,000,000 carriage miles. Casks and transporters shall be designed for ease of inspection, maintenance, and repair.

The cask interface guidelines provide design guidance and establish the degree of standardization required to achieve system efficiency, yet allow flexibility for design innovation. Some of the key topics addressed by the interface guidelines are as follows:

- Fuel assembly designs for which cask designs should be optimized; other limited-quantity fuel that should be accommodated if practical

- Ranges for fuel initial enrichment (3.0 to 4.5 w/o U-235) and spent fuel burnup (18,000 to 35,000 MWD/MTU for PWR fuel and 15,000 to 30,000 MWD/MTU for BWR fuel)

- Spent fuel age (10-year-age design basis; evaluate capability to accommodate 5-year-age with internal design modifications)

- Technical evaluations of nonroutine payloads (e.g., impact of failed fuel, consolidated fuel, short-cooled fuel, etc.)

- Containment, shielding, criticality safety, and materials compatibility guidelines

- Temperature and pressure limits

- Mechanical requirements for spent fuel protection

- Physical dimensions and operational requirements for casks and for cask/transporter combinations

- Crane hook weight limits (100 tons for rail/barge casks) and gross vehicle weight limits (80,000 lb for legal-weight trucks and 263,000 lb for railroad cars)

- Design guidelines for tiedown systems, lifting/handling systems, impact limiters, other ancillary equipment, etc.

- Design guidelines for cask loading and unloading, draining, drying, sampling, purging, cooldown, leak-testing, etc.

The cask performance requirements and interface guidelines are being reviewed during the cask development process to determine whether changes would improve cask fleet optimization. Decisions on possible changes to the cask system performance requirements and interface guidelines will be supported by: (a) results of trade-off studies performed by the cask development contractors, (b) updated information on utility cask handling capabilities and operational plans (e.g., fuel exposure and fuel age at shipment), and (c) life-cycle cost evaluations of suggested changes.

Preliminary Design Status

All of the five cask development contractors (two for legal-weight truck casks, three for rail/barge casks) are nearing completion of the preliminary design phase. Since the start of preliminary design, each contractor has held one or more meetings with NRC personnel responsible for cask certification to discuss preliminary design concepts and plans for resolving cask certification issues. Review of draft preliminary design packages will be initiated as they become available; these reviews are expected to be completed during the latter half of 1989. The final design phase will be initiated by each contractor upon approval of the completed preliminary design report.

Currently planned legal-weight truck cask payloads are 3/7 (i.e., 3 PWR or 7 BWR fuel assemblies) and 4/9. The three rail/barge cask capacities range from 21/48 to 26/52. For comparison purposes, typical existing spent fuel cask capacities are 1/2 for legal-weight truck casks and 10/24 for rail casks. Thus it appears that the desired significant increase in cask payloads will be achieved.

The preliminary designs being developed by the five cask contractors exhibit both diversity in design approaches and design innovation; both attributes were encouraged by the initial request for proposals. Several structural and shielding materials are included in the five designs: (a) cask body materials include stainless steel, ferritic steel, and titanium, (b) both lead and depleted uranium gamma shields are used, (c) internal baskets fabricated from stainless steel and aluminum alloys are being designed, and (d) neutron shielding materials include boronsilicone, borated concrete, borated polyethylene, and a borated hydrogenous structural polymer material. Similarly, impact limiter design concepts include structures fabricated from aluminum honeycomb, balsa wood, and polyurethane foam. One cask design utilizes an innovative fastening device for the closure lid which may facilitate cask handling operations and reduce occupational radiation exposure. Another cask design employs a noncylindrical shape for the cask internal cavity which more closely conforms to the spent fuel array; this innovative design may enable an increased cask payload by virtue of the reduced cask body weight. Even though some of the materials and design concepts present in the five preliminary designs are novel and may require extensive justification during the NRC certification process, they offer potential benefits that warrant the additional effort.

Cask System Testing

Several types of testing activities will be performed in support of the cask system design and development process. The primary objectives of these tests are to verify engineering and safety analyses, facilitate the cask certification process, ensure that manufactured items comply with design specifications, and verify that the casks and associated ancillary systems perform their intended functions. Another benefit of the planned testing activities is increased public understanding of, and confidence in, cask operational and safety features.

Three types of testing fall within the responsibilities of the cask development contractors:

- Engineering Tests -- These tests are performed on nonstandard materials and components or unique design configurations to characterize their performance in the specific cask application.

- Design Verification Tests -- Design verification testing is defined as those tests used to verify that the cask system design is capable of meeting the regulatory requirements for normal and accident conditions, as specified in 10 CFR 71. To the extent possible, these tests will be conducted using 1/4-scale (or larger, with DOE approval) casks, and perhaps selected full-scale cask components.

- Acceptance Tests -- These tests are nondestructive evaluations performed on each full-scale cask prototype to ensure that fabrication was in accordance with design specifications and conditions specified in the cask certification application.

When cask prototypes have been delivered to the DOE by the cask contractors, performance evaluation tests will be performed by the DOE and its contractors to evaluate overall cask system performance in cask fleet applications. Examples of the types of performance evaluation tests that may be performed include the sequential operations associated with cask loading and unloading, intermodal transfers, draining and decontamination operations, maintenance operations, automated handling tests, etc. If the performance evaluation tests indicate that cask system design changes are warranted, these changes can be made prior to cask fleet procurement.

CASK SYSTEMS TECHNOLOGY DEVELOPMENT

The cask development contractors have the responsibility for developing cask designs and obtaining NRC certification of those designs. This responsibility includes evaluating and justifying the use of innovative design concepts and materials. However, some technology development tasks are of potential generic benefit to the entire CSDP, and can best be accomplished with a central focus by a DOE national laboratory. Some of the technology development tasks which are currently being performed by Sandia National Laboratories are as follows:

- **Burnup Credit** -- The feasibility of taking credit for spent fuel burnup in cask criticality safety analyses is being evaluated. This activity includes development of measurement systems, operating practices, and calculational methods which will be acceptable from regulatory and operational standpoints. Potential benefits include increased cask payloads and simplified cask designs.

- **Source Term** -- Standardized methodologies are being developed for evaluating compliance with cask containment requirements using a source term approach. With this approach, the allowable leakage rate is based, in part, upon the amount of radioactive material inside the cask which is available for dispersal (the source term). Potential benefits include reduced time, cost, and radiation exposure associated with leak testing and cask maintenance activities.

- **Computer Code Benchmarking** -- Selected computer codes used for cask design and certification are being benchmarked by comparing their results with known results obtained by other methods. Experimental verifications are included as necessary.

- **Materials and Component Development** -- Materials evaluations and component development activities are being performed in cases where several cask designers have common data needs.

- **Other Technology Development Activities** -- Additional generic technology development and technical support activities are performed on an as-needed basis. Examples of current tasks include investigations of the cask "weeping" phenomenon and demonstrations of robotic technology for remote cask handling.

CONCLUSIONS

The new generation of spent fuel shipping casks currently being developed will have significantly higher capacities than existing casks, which will result in a reduced number of shipments and corresponding reductions in transportation costs and risks. The diversity of designs being developed will provide numerous options for the cask fleet composition, flexibility in transportation operations, and contingency positions in case of problems with a particular cask design. Several innovative design features will potentially contribute toward cask payload optimization, improved cask handling operations, and reduced cask turnaround times and occupational radiation exposures. Results from the cask systems technology development tasks show promise for further improvements in cask design and operation and in the technical bases for resolving NRC certification issues. The current design development and technology development work is also expected to benefit future cask designs for other waste forms.

DISCLAIMER