CASK PERFORMANCE AND INTERFACE SPECIFICATIONS FOR SHIPMENT OF US SPENT LIGHT WATER REACTOR FUEL*

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Abstract

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Preliminary cask physical performance specifications and interface guidelines have been defined to support the development of a family of casks and transporters for shipments in the United States of America of spent light water reactor fuel. These shipments will be made from US commercial reactor facilities to high level waste receiving facilities. The specified hardware consists of both truck and rail/barge casks, along with their associated transporters.

INTRODUCTION

With enactment of the United States Nuclear Waste Policy Act (NWPA) of 1982 [1], the U.S. Department of Energy (DOE) established a commitment to ensure that a safe, environmentally acceptable and cost-effective transportation system be operable when needed for civilian waste shipments. Under provisions of the NWPA, the DOE will take title to spent light water reactor (LWR) fuel at U.S. commercial reactor facilities and arrange for the transport to high level waste disposal sites. All casks used for LWR fuel transport will be certified by the U. S. Nuclear Regulatory Commission (NRC).

As further discussed in the Office of Civilian Radioactive Waste Management (OCRWM) Mission Plan [2] and Transportation Business Plan [3], a multi-phase program has been established by DOE to support the development by private industry of the necessary transportation capability to ship nuclear waste from

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existing utilities and waste processing facilities to storage facilities that have yet to be built. The facilities from which the nuclear waste will originate have significantly different fuel handling features and transportation interfaces. As such, future transportation system hardware must have considerable versatility in order to interface with a large majority of the facilities within the entire system.

The OCRWM transportation system development program consists of four phases: 1) systems definition; 2) engineering development and certification; 3) cask fleet procurement and carrier negotiations and 4) transportation operations. It is expected that some phases may overlap for several years. The systems definition phase, currently underway, includes definition of the waste forms to be shipped, evaluation of transportation modes and logistics and specification of optimal packaging design envelopes for each of the modes (truck, rail, barge, etc.). The engineering and development phase will be initiated soon with the issuance to private industry of the first request for proposals (RFP) for cask development. The first RFP, designated as Transportation Systems Acquisition Initiative 1, will result in contracts being placed with private companies in the U. S. to develop cask designs for use in shipping spent nuclear fuels from reactors to disposal system facilities. Later RFP's may be issued to develop casks for use between disposal system facilities (designated as Initiative 2) and for specialty purposes (designated as Initiative 3). Fleet procurement and carrier negotiations are expected to begin in the early 1990s with full-scale transportation operations scheduled to start in the mid to late 90s. Prior to full scale operations, a mini-fleet will be tested throughout the system (reactors, processing facilities and storage site(s)) for approximately two years. Necessary modifications to any of the cask designs or interfaces used for the full-scale fleet will be initiated following evaluation of early operational tests.

Conditions for shipping spent fuel at the turn of the century could differ considerably from those existing in the U.S. today. The number of future shipments to repositories will represent a substantial increase over the number of current shipments. Also, future casks will be required to accommodate much older (time out of reactor) spent fuel. Since current generation casks are predominantly designed for much younger spent fuels, the development of more efficient "new generation" casks is warranted because of the potential large increases in payload capacity. DOE will also encourage private industry to be innovative in designing features to enhance safety and operational efficiency.

The Initiative 1 casks will be designed by several suppliers in order to diversify sources and design options for eventual fleet units. Casks for each mode of surface transportation and practical multimodal combinations will be developed in order to establish a complete matrix of acceptable options. However, some standardization of interface hardware and cask requirements is necessary for an efficient operational system. DOE is developing the performance specifications and interface guidelines reviewed in this paper to both define requirements for casks to be procured and to evolve the necessary standardized interfaces for an efficient system. The preliminary specifications are intended to be the minimum necessary and sufficient requirements to support the preliminary design of a family of shipping casks. They are not intended to restrict designer creativity. The cask family consists of both truck and rail/barge casks along with their associated dedicated transporters where appropriate. An intermodal capability is required for cask units.

SPECIFICATION DEVELOPMENT STRATEGY

In order to establish consistent requirements for all spent fuel casks to be used in the U.S., Sandia National Laboratories under the direction of DOE has developed a set of cask performance specifications and interface guidelines for the cask-development initiatives. It was recognized that the major design constraints on a "From Reactor" transport fleet are defined by regulations and current U.S. power plant facility interfaces. Consequently, the primary goal has been to define cask specifications that envelop an optimally determined majority of the existing facilities and yet are sufficiently nonrestrictive that designer latitude exists for establishing a highly efficient and safe system.

At the beginning of the specification development process, a U.S. industry-wide survey was completed to identify, accumulate and evaluate transportation system data and regulatory requirements having a significant impact on future cask designs. This included defining cask constraints caused by conditions at existing U.S. reactors and potential transport modes. Following the initial compilation of cask-interface data and recommendations for performance criteria, a set of specifications was drafted [4]. These draft specifications were subjected to an industry peer review and a public comment period. The draft performance and interface specifications contain requirements grouped into the following categories:

(1) Cask Physical Performance Specifications
(2) Waste Form to Cask Interface Guidelines
(3) Cask to Transporter Interface Guidelines
(4) Cask/Transporter to Facility Interface Guidelines

Performance goals are based on a philosophy of encouraging designers to increase safety, handling efficiency and automation capability, to decrease cask servicing and turnaround requirements and to reduce public and occupational exposure.

The preliminary Cask Physical Performance Specifications and Interface Guidelines will be revised periodically as more definitive information becomes available from both design and parallel research activities. A major source of revisions to the specifications will come from work being performed by the cask designers themselves. For example, where standardization is appropriate, the best ideas of the development contractors will become the standards for all designs. The performance specifications and interface guidelines will be updated upon completion of preliminary designs for new casks.

A second source of input to the specifications will be other development activities currently underway by private companies and DOE contractors. For example, cask operational and physical design constraints will be identified by developments on advanced cask handling concepts using remote-automated techniques. A compilation of existing U.S. reactor facility interface information revealed that a more detailed site-specific data collection is warranted. Results from this more detailed interface data collection will be incorporated into the specifications. Spent fuel logistics assessments are being conducted to better identify the characteristics of the spent fuel expected to be transported during the projected cask fleet lifetime. These assessments also include identifying reasonable approaches for reducing risks to the public and occupational sectors. Advanced conceptual designs of repository receiving facilities will have an impact on the interface guidelines.

A third source of future input to the cask performance specifications and interface guidelines will be resolution actions planned to address outstanding technical issues. DOE has identified a number of technical issues that affect a broad spectrum of cask designs and has initiated tasks to address them. The resolution of these issues could have a significant impact on cask design requirements. These issues include the allowance of fuel "burnup credit" in cask design; the definitions of releasable spent fuel source terms and containment evaluation methodologies during both normal and accident conditions of transport; the acceptability of alternative materials and brittle behavior modeling techniques; the acceptability of inelastic (elastic-plastic) analysis techniques; design requirements for cask tiedown components and tiedown system analyses; consolidated rod heat transfer modeling; cask surface contamination and in-transit "weeping"; the definition of sufficient storage/transport cask in-service monitoring requirements and preshipment inspections and the identification of cask drop orientations for normal condition of transport evaluations.

Consequently, the cask performance specifications and interface guidelines should be viewed as requirements that exist in preliminary form at the present but will evolve significantly over the next several years. In addition to delineating detail requirements for casks to be used as part of the U. S. waste management system, the specifications are a major tool in the process of implementing DOE's goals for establishing a safe and efficient transportation system. The major items of the current preliminary specifications are reviewed in the following sections.

PRELIMINARY CASK PHYSICAL PERFORMANCE SPECIFICATIONS

There are three basic requirements that all cask system designs must adhere to: the casks and transporters must be designed in accordance with all applicable U.S. regulations; design, prototype fabrication and testing activities must be conducted in accordance with acceptable quality assurance programs [5, 6, 7] and the casks must receive a Certificate of Compliance from the U.S. Nuclear Regulatory Commission.

In addition, a number of performance requirements have been included to minimize public and occupational radiation exposures and transport risks. The carrying (payload) capacity for each transport mode will be maximized to the extent possible. System turnaround, the time between the receipt of an empty or loaded cask/transporter and the subsequent release of that cask/transporter, is limited at Federal facilities to less than 8 hours for a truck-transported cask and 12 hours for a rail-transported cask. At utility reactor facilities, the design turnaround requirement is less than 12 hours for truck casks and 18 hours for rail casks. Intermodal transfer capability is required for all casks with a limit on transfer time of less than 4 hours.

All cask operations from transporter/cask receipt through transporter/cask release must be capable of being accomplished using remote, remote-automated and contact or "hands-on" techniques. Remote techniques increase the distance of operating personnel from the cask using tool extensions, supplemental shielding, or manipulators. Remote-automated techniques use robotic technology, intelligent machines, or special handling machines to perform cask operations. Interfaces for remote-automated techniques will be specified by DOE. In addition, some handling and operational interfaces will be standardized for all cask models.

A significant portion of turnaround time at reactor facilities is expended decontaminating a cask after wet pool loading. As such, all system components that potentially can come into contact with radioactive material must be designed to limit surface contamination and weeping of the cask surface (without undue operational constraints) and for ease of decontamination.

Materials used in the structural fabrication of the cask containment boundary must either meet the requirements of the American Society of Mechanical Engineering Boiler and Pressure Vessel Code, Sections II and III, or be supported with independently verified materials data. Materials and material behavior not addressed by the ASME Code (such as nonlinear stress-strain behavior and strain-rate dependent yield and flow data) may be considered provided property values used for analysis are justifiable and supported with verified test data.

All structural components that are critical for maintaining shield or containment integrity will undergo scale-model (or full-scale if preferred by the designer) design verification/ certification testing. Prototypes must successfully complete operational and acceptance testing.

PRELIMINARY CASK INTERFACE GUIDELINES

The transportation system is made up of the component groups that are illustrated in Figure 1. There are three major hardware interfaces between components. These are: 1) Waste Form to Cask; 2) Cask to Transporter; 3) Cask/ Transporter to Facility. Each of the three interface areas involves a wide variety of hardware items, equipment tools, design considerations and regulatory guidelines. For example, the waste form to cask interface involves the handling of intact as well as disassembled fuel assemblies that have a range of irradiation, decay histories and physical dimensions.

Numerical values used in the interface guidelines are design envelopes that allow a cask to serve the great majority of reactors (greater than 80%). The interface guidelines are based on dimensional bounding envelopes and are not intended to define a specific requirement. The limits are not defined by the "lowest common denominator" or the most restrictive interface constraint if it was felt that a given constraint would have a negative impact on overall system efficiency. The casks developed under the Initiative 1 RFP should efficiently transport 80 to 95% of the spent fuel assemblies from reactors. The remaining amounts would be transported in less optimal configurations of casks developed under Initiative 1 or in future specialty casks procured under Initiative 3.

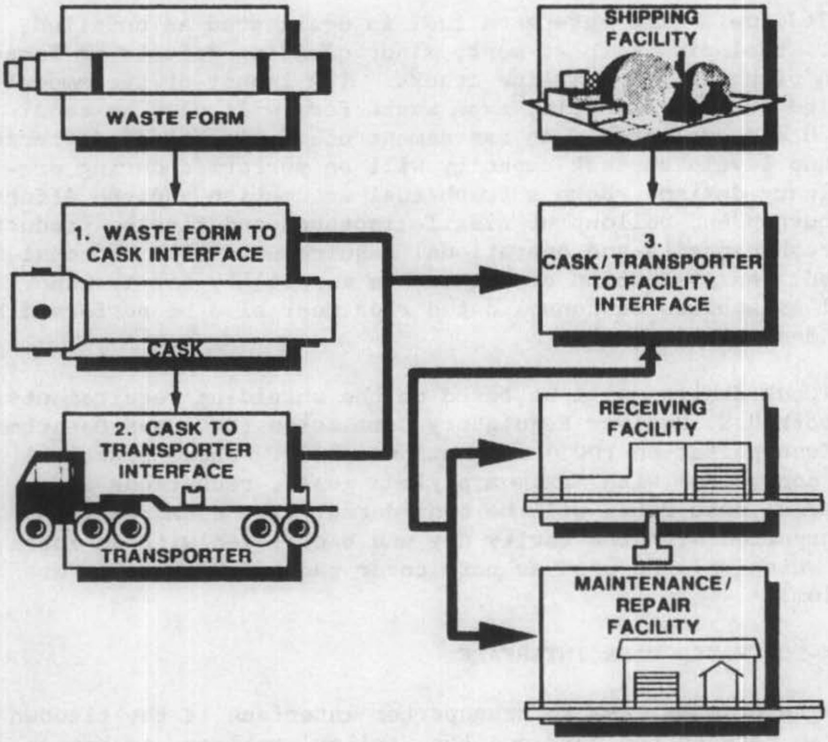

FIG. 1. Nuclear waste transportation system interfaces.

WASTE FORM-TO-CASK INTERFACE

Initial spent fuel logistics assessments were performed using a transport rate of 3000 metric tons of uranium (MTU) per year and an "oldest" first basis for spent fuel movement from reactor facilities to receivers. Fuel assembly types listed in Reference 4 were determined to constitute the majority of intact assembly types that must be transported in the U.S. Nonstandard or limited quantity spent nuclear fuels are not required to be accommodated in the Initiative 1 casks if their accommodation would decrease payload for other fuels. However, the designer must identify which of the additional light water reactor assemblies not listed as required can be physically accommodated (potentially in a different, less-efficient basket arrangement).

The reference fuel age or time since discharge from the reactor core is 10 years. The accommodation of fuel with an age of 5 years will also be evaluated. Different or less efficient basket configurations may be used for this shorter cooled fuel. The reference fuel is designated as unfailed, i.e. fuel pins with at most, minor cladding defects no larger than pinholes and hairline cracks. The impact of accommodating failed fuel as a special-case waste form will also be considered and evaluated. An assessment of the impact of different burnup levels on cask capacity will be performed during preliminary design. Both a fresh fuel assumption and the effect of burnup and buildup of fissile isotopes and fission products on cask capacity and operational requirements will be considered. An evaluation of the cask's capability for transporting fuel assemblies as consolidated rods must also be performed by the designer.

Cask designs will be based on the shielding requirements of both U.S. Nuclear Regulatory Commission (NRC) and Department of Transportation (DOT) regulations [5,8]. Where practical and consistent with maximum payload goals, reductions in external dose rates will be considered. The casks will be transported with the cavity dry and backfilled with an inert gas which will be used as both cover gas and heat transfer medium.

CASK-TO-TRANSPORTER INTERFACE

The primary cask to transporter interface is the tiedown system between the cask and the trailer, railcar, or barge. The cask designer will make a recommendation for the mechanical requirements of the cask, transporter and interface tiedown components that is based on consideration of the complete tiedown system. Transporter or skid mounted tiedowns should be integrated with the methods and equipment used for laying down and uprighting the cask.

Intermodal features are required for all casks: truck to rail, truck to barge and rail to barge. Intermodal transfer can be either roll on/off or cask transfer with the use of a skid.

CASK/TRANSPORTER TO FACILITY INTERFACE

Cask and transporter sizes and weights are limited by transport restrictions and existing reactor facilities. Bounding envelopes for casks, highway systems and rail systems have been developed that allow future casks to efficiently interface with a majority but not all reactor sites. Cask and transporter designs should allow easy access for visual and remote inspections, radiation and contamination surveys and other necessary preparation operations prior to transporter loading and unloading. For safeguard requirements, open areas must be clearly visible. Tamper-indicating seals are required for closed areas, particularly components whose removal would provide access to the cask cavity.

During transport, the cask will be in a horizontal position. Transporter loading and unloading will be accomplished with a single vertical lift for normal operations and a horizontal lift with skid for cask transfer intermodal operations. Cask identification, washdown, survey, leak testing, cavity draining, purging, drying, gas sampling and cooldown must be able to be performed either manually or using remote-automated methods. Casks must be capable of loading and unloading in wet or dry environments and have a sealing surface for connection to a hot-cell enclosure.

CONCLUSIONS

Preliminary cask performance specifications and interface guidelines have been prepared as part of the process of developing new cask systems for transporting spent nuclear fuels from U. S. power reactors to waste disposal facilities. The specifications are expected to evolve further over the next several years as preliminary cask designs and other research activities are completed. Major items emphasized in the specifications are as follows:

1. As Low As Reasonably Achievable radiation exposure and payload maximization are major goals.

2. Specifications are not driven by worst-case constraints in order to achieve a better overall system optimization.

3. Remote-automated handling capability is required as well as traditional manual handling.

4. An extensive testing program is required for all designs.

5. Intermodal transport capability is required for all casks.

REFERENCES

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