A Defense High Level Waste Shipping Cask Design

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Abstract

In the late 1970's, the Department of Energy initiated a program to develop a safe and efficient transportation system for Defense High Level Waste. The specific activities include designing, testing, certifying and fabricating a prototype legal-weight truck cask system. This paper highlights the design of this state of the art cask.

INTRODUCTION

Transport of defense high-level nuclear waste from reprocessing sites of the U. S. Department of Energy (DOE) is required to permanent disposal facilities. In order to end interim storage, the waste must be immobilized and prepared for shipment to a geologic repository. Capabilities must be developed by the DOE to transport waste from sites located in South Carolina, Idaho, and Washington. Since defense high-level waste (DHLW) immobilization facilities are scheduled to begin operation in 1989 at the Savannah River Plant in South Carolina and in 1990 at the Hanford Reservation in Washington, shipment of waste from both sites is scheduled to begin in 1998. The Idaho National Engineering Laboratory is scheduled to begin immobilization of waste and off-site transport in 2008.

Prior to the initiation of large-scale transportation operations in 1998, limited quantities of DHLW will be shipped to the Waste Isolation Pilot Plant (WIPP) in New Mexico, where research and development experiments will be performed on this waste. Solidified waste from the Defense Waste Processing Facility (DWPF) located at the Savannah River Plant is scheduled to be transported to WIPP in 1989 for these experiments.

In response to the need for a safe and efficient transportation system for DHLW, a program was initiated at Sandia National Laboratories by the DOE in the late 1970's. GA Technologies, Inc. was selected to provide the detailed design of the shipping system. This shipping system must be certified by the DOE and will be designed, fabricated, tested and operated in accordance with all applicable DOE and U. S. Department of Transportation (US DOT) regulations.

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SYSTEM DESIGN

The conceptual design for this truck cask was first reported in Ref. 1. The DHLW shipping cask is designed to meet a legal truck weight limit of 36,288 kilograms (80,000 pounds). The complete system as shown in Figure 1 includes the loaded cask, the semi-trailer with supports and the tractor. Design weight allowances for various system components are also shown in Fig. 1. The supports and tiedowns consist of the semi-trailer mounted supports and the associated hardware required to secure the cask during transport. Use of a heavy duty tractor and a dedicated semi-trailer provides for a flexible system.

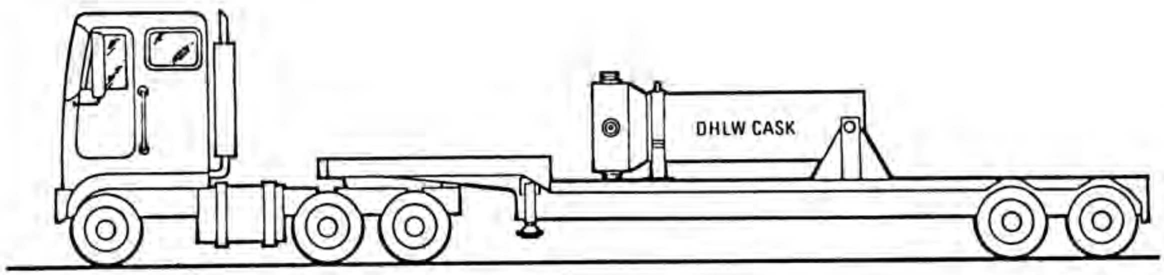
PACKAGE CONTENTS

The DHLW shipping cask is designed to transport one canister of solidified DHLW produced by the DWPF. The canister contains sludge (minimum age of 5 years) and supernate (minimum age of 15 years) in a borosilicate glass matrix. Subsequent to pouring the molten waste into the canister, the outer surface is cleaned and decontaminated. The canister is sealed by fusion welding a plug into the opening at the top of the canister.

The design basis canister is 610mm (24 in.) in diameter by 2997mm (118 in.) long and has a loaded weight of 2356 kg (5195 lb). The canister material is type 304L stainless steel. Each canister contains approximately 282,000 Ci of activity, has a surface radiation dose rate of 8900 rem/hr, and produces 750 W of decay heat.

PACKAGING DESIGN

The packaging, as shown in Fig. 2, is 97.8 cm to 124.5 cm (38.5 in. to 49.0 in.) in diameter and 410.8 cm (161.75 in.) in length. It is configured with an outer body of type 304 stainless steel and an inner gamma shielding liner of depleted uranium contained by inner and outer shells of stainless steel. This configuration was chosen to maximize the waste loading of DHLW while minimizing the external dose rates and staying within the legal weight truck limit. The defense high-level waste form does not require neutron shielding. The cask components are designed to serve one or more of three functions: energy absorption, radiation shielding, and



UNIT	WEIGHT	
TRACTOR	7,938 kg	(17,500 lb)
TRAILER/SUPPORTS	5,443 kg	(12,000 lb)
CASK & CONTENTS	22,453 kg	(49,500 lb)
PRACTICAL LIMIT	35,834 kg	(79,000 lb)

Fig. 1. Defense high-level truck cask system.

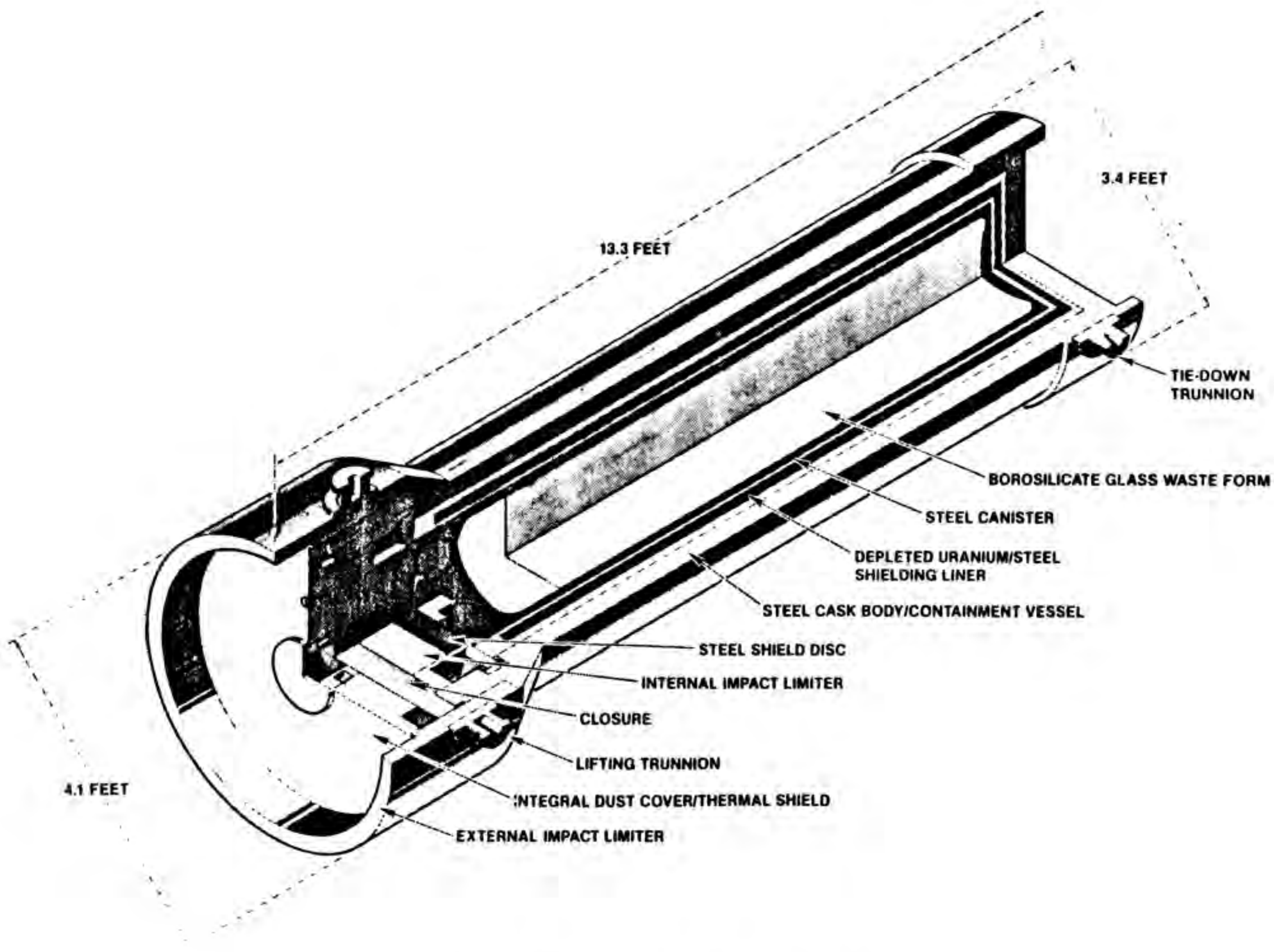


Fig. 2. Defense high-level waste truck cask.

containment of the waste form. Those components that provide physical waste containment are referred to as primary containment boundaries. Each component will be discussed in the following paragraphs. To minimize the radiation dose to the facility operating personnel, the DHLW shipping cask transportation system is designed such that remote handling techniques can be used for all normal operations where personnel radiation exposure exists.

Cask Body

The three inch thick stainless steel walls of the cask body are designed to ensure the structural integrity of the cask and to provide some radiation shielding. The cask body in conjunction with the outer closure and double elastomer O-ring seals form a primary containment boundary. During impacts on the bottom of the cask, a ring impact limiter acts as an energy absorber. Although the impact limiter is an integral part of the cask body, it is not a primary containment boundary component. During impacts on the side of the cask, a ring impact limiter located in line with the two upper lifting trunnions acts as an energy absorber.

Shielding Liner

Depleted uranium in the form of a removable shielding liner provides radiation shielding. It is restrained from axial movement by a segmented shear ring bolted to the top rim of the shielding liner. The shear ring extends into a circumferential groove machined into the inside wall of the cask body. The cask design allows this liner to be removed and replaced by different liners having other inside diameters. This feature allows the transport of larger or smaller sized waste forms having different shielding requirements than the DWPF waste. Other shielding liner designs could permit this cask to accommodate other waste forms such as commercial high level waste or remote-handled transuranic waste.

External Impact Limiter

This component is a stainless steel ring attached to the closure end of the cask and absorbs energy by plastic deformation. Since the ring extends beyond the outer closure, it protects the closure bolts and seals from excessive deformation during the hypothetical accident condition 9 meter (30 foot) free drop onto an unyielding surface. This ring, which is a separate part fitted to the cask body, protects the containment boundary near the closure from plastic deformation.

Closure Assembly

The closure assembly, which is part of the primary containment boundary, consists of a stainless steel plate that includes a double o-ring seal, a leak test port and a gas sample port and is secured to the cask body by twenty-four Inconel 718 bolts. An internal aluminum honeycomb impact limiter assembly is bolted to the inner face of the closure. A plate distributes the load between the waste canister and impact limiter to limit the load transmitted to the closure and closure bolts during a 9 meter free drop onto an unyielding surface. Both the closure plate and the internal impact limiter have radiation shielding functions.

Integral Thermal Shield

The function of the thermal shield is to protect the elastomeric seal gaskets, the cavity gas sample port, and the seal leakage rate test port built into the closure from excessive temperatures during the hypothetical accident condition thermal event. The thermal barrier is bolted to the outside face of the closure. It consists of two thicknesses of stainless steel honeycomb contained between and bonded to stainless steel sheets. This nonstructural component must remain attached throughout the 9 meter drop and the 1 meter puncture hypothetical accident sequence. The damage expected during those accident events will not substantially reduce its effectiveness in protecting the seals.

Trunnions

The trunnions are designed to safely support the DHLW shipping cask during handling and transport. They are also designed to deform or fail during the hypothetical accident conditions in a manner that will not breach or endanger the containment boundary.

STRUCTURAL ANALYSIS

The closure end of the DHLW shipping cask is protected by a stainless steel cylindrical ring impact limiter that is sculptured to provide variable stiffness to accommodate both corner and end drops. For the hypothetical accident condition of a 9 meter drop event, the impact limiter protects the closure seals and keeps the containment boundary near the closure seal from deforming plastically. This protection assures that the seals will not fail when subjected to the hypothetical accident conditions of transport. A ring impact limiter is also provided at the lower end of the cask to protect the containment boundary. The available energy during the drop is absorbed through plastic deformation of the impact limiters and the cask body which is a part of the containment boundary. The design criteria is based on ASME Code, Section III, Appendix F, to define allowable inelastic limits. Two inelastic dynamic response finite element programs, HONDOII and DYNA3D, were used to analyze the impact events. Different drop orientations provide the most severe loading to different portions of the containment boundary. The closure end drop provides the most severe loading to the closure and closure bolts. Only minimal plastic deformation of the closure occurs while the closure bolts remain well below yield. The center of gravity over the lower corner drop and the side drop provide the most severe loading for the remainder of the containment boundary. The DYNA3D analysis showed that the drop energy could easily be converted to strain energy by plastically deforming the impact limiter and plastic deformation of the cask body but still keeping the stresses within allowables.

FUTURE ACTIVITY

Fabrication of a half-scale model of the DHLW truck cask has been initiated with expected delivery during FY85. Regulatory testing on the model will be conducted at Sandia National Laboratories to verify the adequacy of the structural analysis and cask design. This series of destructive tests includes 9 meter drops onto an essentially unyielding surface for several impact orientations. A one meter drop onto a mild steel punch will follow the 9 meter drop events. Following evaluation of the test results, a prototype will be fabricated and certified by the DOE. Initial shipments of immobilized waste from the SRP are scheduled to be transported to the WIPP in 1989.

REFERENCES

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