ABSTRACT

General Atomics (GA) is developing final designs for two dedicated legal-weight trailers to transport the GA-4 and GA-9 Spent-Fuel Casks. The basic designs for these high-capacity, high-strength trailers are essentially identical except for small modifications to account for the differences in cask geometry. We are designing both trailers to carry a 55,000 lb (24,900 kg) payload and to withstand a 2.5 g vertical design load. The GA-4 and GA-9 trailers are designed for significantly higher loads than are typical commercial semitrailers, which are designed to loads in the range of 1.7 to 2.0 g. To meet the federal gross vehicle weight limit for legal-weight trucks, GA has set a target design weight for the trailers of 9000 lb (4080 kg). This weight includes the personnel barrier, cask tiedowns, and impact limiter removal and storage system. Based on the preliminary trailer designs, the final design weight is expected to be very close to this target weight.

INTRODUCTION

General Atomics is under contract to the Idaho Operations Office of the U.S. Department of Energy (DOE) to develop two legal-weight-truck from-reactor spent-fuel shipping casks with trailers. We are developing the casks and trailers to support the Office of Civilian Radioactive Waste Management's (OCRWM) mission to dispose of nuclear wastes at a permanent disposal site. GA's goal is to maximize the number of fuel elements that the transportation systems can safely carry. The GA-4 Cask is being designed to transport four pressurized-water-reactor spent-fuel assemblies, and the GA-9 Cask is being designed to transport nine boiling-water-reactor spent-fuel assemblies. Achieving these capacities requires that the weight of each component of the
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transport system, i.e., cask, trailer, and tractor, be minimized. The use of these high-capacity transport systems will have a large benefit to public safety since the number of shipments by truck will be reduced by at least a factor of four over existing spent-fuel shipping cask systems.

DESIGN REQUIREMENTS

The total weight of the transport system must be less than the federal gross vehicle weight (GVW) limit of 80,000 lb (36,300 kg). GA has allotted 16,000 lb (7,260 kg) for the tractor, 54,000 lb (24,500 kg) for the packaging (cask and spent fuel), 9,000 lb (4,080 kg) for the trailer, and 1,000 lb (454 kg) for margin in case these target weights are exceeded.

GA has elected to design the trailers to the requirements of the proposed "American National Standard for the Design, Fabrication, and Maintenance of Semi-Trailers Employed in the Highway Transport of Weight-Concentrated Radioactive Loads," ANSI N14.30 (Ref. 1). Two key requirements from ANSI N14.30 are (1) the semitrailer shall be designed to withstand a vertical static load of 2.5 times the sum of the live plus dead loads without exceeding the minimum yield strength and (2) the center of gravity of the live plus dead load shall not be higher above the grade than 85.75 in. (218 cm) for a 96 in. (244 cm) wide trailer. The GA-4 and GA-9 trailers are 96 in. (244 cm) wide. ANSI N14.30 also requires that to account for cyclic and dynamic factors, the trailer shall be designed for 1.2 times the combined live and dead loads times the dynamic loading factors. In addition to the loads explicitly specified by ANSI N14.30, we designed the trailer for a 0.3 g lateral load and a 1.5 g longitudinal load.

Two additional DOE guidelines are (1) the trailer should be equipped with a personnel barrier that limits access and limits rain and water spray from reaching the cask surface and (2) consideration should be given to designing the trailers to allow storage of impact limiters on the trailer during facility operations.
TRAILER DESCRIPTION

GA has completed preliminary design of the trailers and is currently in the process of optimizing the final design. The trailers are a single-drop design (Fig. 1) and will be nearly 43 ft (13.1 m) long. The cask and trailer system will have a center of gravity approximately 75 in. (191 cm) above grade. This center of gravity is significantly less than the 85.75 in. (218 cm) maximum center of gravity specified by ANSI N14.30.

In addition to the basic trailer structure and equipment, the trailers have a tiedown system for attaching the cask to the trailer, a personnel barrier to limit access to the cask and protect the cask from rain and water spray, and an impact limiter storage and removal system to facilitate handling of the impact limiters. The impact limiter removal and storage system increases the length of the trailer since space must be provided so that the impact limiters can be stored on the trailer and not interfere with the process of uprighting and removing the cask from the trailer.

Structure

GA selected the single-drop trailer design since we found it to be the design that yields the lowest weight while achieving a center of gravity no greater than 85.75 in. (218 cm) above the grade. The trailer's primary structural members are two custom shaped I-beams that run the length of the trailer. These I-beams are being optimized to meet stress, buckling, and fatigue criteria. The flanges are formed from continuous plates which are welded to custom shaped webs. The compression flange between the gooseneck and rear tandem is an inverted C-section. This flange configuration prevents buckling without adding significant weight. The cross members between the two main I-beams are a combination of I-beams and C-sections. All members are fabricated from T-1 (A514) steel which has a 100 ksi (689 mPa) minimum yield strength.

The trailer decking extends from between the insides of the two impact limiters out to the trailer's maximum width of 96 in. (244 cm) (Fig. 2).
Aluminum cantilevered beams provide the main structural support for the decking. Aluminum tread plate is attached to the cantilevers to provide work space for operational personnel.

**Tiedown System**

The tiedown system consists of four hinged-pillow block assemblies that are located directly above the main trailer I-beams and are attached to the main trailer I-beams by a system of lateral, vertical, and longitudinal beams (Fig. 1). The top covers of the pillow block assemblies rotate about hinges to engage (or release) the cask lifting (front) and tiedown (rear) trunnions. The pillow block assemblies are locked in place by captured bolts which have been designed to facilitate remote handling.

The rear tiedowns are rigidly attached to the trailer and provide vertical, lateral, and longitudinal cask support. The rear tiedowns are used to upright the cask and allow the cask, after the impact limiters have been removed, to be rotated into a vertical position without interference.

We are investigating two designs for the front tiedowns: one where the tiedowns are pinned to the trailer frame and another where the tiedowns are rigidly attached to the frame. In the first design (Fig. 1), the front tiedowns are pinned to the main trailer I-beams such that they provide vertical and lateral support but not longitudinal support. Pinned horizontal bars connect the front and rear tiedowns and form linkages that keep the distances between the front and rear pillow blocks constant. The support pads in the front pillow blocks will be slightly elongated or some free play will be incorporated into the pinned links to compensate for differential thermal growth between the cask and the tiedown system.

In the second design, both the front and rear tiedowns are cantilevered from main trailer I-beams. Therefore, the relative position between the pillow blocks is changed when the trailer camber changes. Loading the cask onto the trailer causes the trailer to deflect approximately 3 in. (8 cm). This changes the trailer camber causing the front and rear tiedowns to rotate in opposite
directions, in turn, decreasing the distance between the tiedowns by almost 2 in. (5 cm). To account for this relative motion between pillow blocks and to account for differential thermal expansion, the support pads of the front pillow blocks would be elongated by approximately 2 in. (5 cm). This will allow the trunnions to slide longitudinally without significantly loading the front tiedowns.

**Trailer Equipment**

The trailer design includes a Neway air-ride suspension system with automatic leveling capabilities. This suspension system adapts to axles with "S" cam or wedge brakes, which will allow the trailer brakes to be matched to those of the tractor. Also specified are Olympic 16-in. (41-cm) travel landing gear. Aluminum fenders and wheels will be utilized for additional weight savings.

**Personnel Barrier**

The GA-4 and GA-9 trailers have no regulatory requirement to provide a personnel barrier for the casks. To comply with the DOE suggested guideline to equip the trailer with a personnel barrier that limits access and limits rain and water spray from reaching the cask surface, we have proposed a personnel barrier that consists of (1) an aluminum splash pan attached to the main trailer I-beams and located below the cask and impact limiters, (2) the trailer decking, and (3) a high-strength fabric cover, possibly a Kevlar composite material, stretched over the two impact limiters and attached to the trailer and trailer decking.

The splash pan will limit water spray from reaching the cask surface and will prevent access to the cask from below the trailer. The decking provides a place for operational personnel to stand while working with the cask or tiedown system, provides a place to attach the cover, and provides ventilation into the personnel barrier through the holes in its aluminum tread plate. The cover will limit access to the cask from above and to the sides of the cask, and will limit rain and spray from reaching the cask surfaces.
Additional ventilation holes will be provided as needed in the splash pan and top of the cover to provide natural air circulation through the personnel barrier. The ventilation holes will be designed to limit rain and water spray from reaching the cask surface.

Impact Limiter Removal and Storage System

The impact limiters will be removed from the cask and stored on the trailer before the cask is removed from the trailer. After the cask is returned to the trailer, the impact limiters will be re-installed onto the cask. The purpose of the impact limiter removal and storage system is to facilitate the removal and installation of the impact limiters and to allow the impact limiters to be easily moved to a storage position that does not interfere with uprighting the cask or removing from or replacing it onto the trailer.

The conceptual design for the impact limiter storage and removal system is a system of rollers on rails that would be engaged to support the impact limiters during their installation and removal from the cask and provide a means to easily move them to their storage locations. This roller system will be designed to facilitate using either manual or remote handling techniques.

DESIGN AND ANALYSIS

GA evaluated various standard and nonstandard semitrailer configurations to find a trailer design which could achieve the 9000 lb (4080 kg) target weight and meet the strength and center of gravity requirements specified in ANSI N14.30. We found that a standard flatbed semitrailer could be designed to meet the 9000 lb (4080 kg) target weight, but would have a center of gravity that is higher than allowed by ANSI N14.30.

GA also evaluated trailers with a cradle configuration (Fig. 3). With this design the main I-beams are spread so that the cask can be lowered between them. This design can achieve the center of gravity required by ANSI N14.30, but was found to yield a design that is heavier than the single-drop design.
Before choosing T-1 steel, GA evaluated other candidate materials. Aluminum members were not used because of weld fatigue concerns. Titanium was also considered but rejected because of cost, difficulty with welding, and the unfamiliarity of the material by the semitrailer industry.

Currently, the trailer structure, the tiedown system, and other components are being optimized to minimize the weight of the trailer and to obtain the lowest practical cask center of gravity. We are using the ANSYS computer program to optimize the structure. The techniques described in the American Institute of Steel Construction (AISC) (Ref. 2) are being used to ensure adequate margin against buckling of the structural members.

Fatigue is being evaluated using ASME fatigue allowables (Ref. 3). The trailers are being designed to keep stress levels below the endurance limit of the material. Stress concentrations which could reduce fatigue life are being avoided. The open design of the trailers simplifies periodic weld inspections.

GA is working closely with trailer equipment manufacturers and the tractor designer to ensure that the trailer components are not only lightweight, but are also reliable and compatible with tractor requirements and drivers' needs.

CONCLUSIONS

Our evaluation of the GA-4 and GA-9 trailer designs indicates that the final trailer designs will achieve our goals of developing trailers that (1) are lightweight [gross trailer weight at or very close to 9000 lb (4080 kg)], (2) have high capacity [55,000 lb (24,900 kg) payload], (3) have high strength (able to withstand a vertical static load of 2.5 times the sum of the live plus dead loads without exceeding yield), (4) have low centers of gravity [approximately 75 in. (191 cm) above grade], and (5) are safe and reliable. The safety and reliability will be achieved by having a high-strength, low center-of-gravity design and providing adequate design margins for buckling and fatigue.
REFERENCES


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FIGURE 1  GA-4/GA-9 CASK HIGH-CAPACITY HIGH-STRENGTH TRAILER
FIGURE 2  GA-4/GA-9 CASK TRANSPORT SYSTEM WITHOUT PERSONNEL BARRIER
FIGURE 3 CRADLE TRAILER DESIGN WAS TOO HEAVY