DEVELOPMENT OF A TRAILER DESIGN FOR TRANSPORT OF SPENT FUEL SHIPPING CASKS

Tom L. Bridges
Idaho National Engineering Laboratory
EG&G Idaho, Inc.

Chad Taylor
General Atomics

ABSTRACT

General Atomics is under contract to the U.S. Department of Energy to develop two legal-weight truck from-reactor spent-fuel shipping cask systems, including transport trailers. In an effort to keep the cask capacities as high as possible, a target design weight of 9,000 lb was established for the trailers. These trailers must be safe, reliable, and of high integrity. The design of these trailers is complete and one prototype trailer has been fabricated, static load tested, and subjected to a short road test. The test results to date demonstrate that the design objectives have been met. Additional durability and operational testing of the prototype trailer is planned. Upon completion of this additional testing, verification of the worthiness of the trailer designs to perform their intended function reliably and safely will be established.

INTRODUCTION

The U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM) is supporting the development of cask systems for the transport of spent nuclear fuel. General Atomics (GA) is under contract to DOE to develop legal weight truck (LWT) cask systems (gross vehicle weight less than 80,000 lb) for the shipment of both pressurized water reactor (PWR) and boiling water reactor (BWR) spent fuel. These systems include the casks, trailers, and ancillary equipment. A goal of the program is to maximize the number of fuel assemblies that the transport systems can safely carry. High-capacity transport systems provide economical and public safety benefits, since the number of shipments required to transport the spent fuel inventory to interim or permanent storage locations is greatly reduced. To maximize the payload for each shipment, GA has allocated 9,000 lb for the trailers. Developing a trailer design within this weight restraint, without sacrificing safety and reliability, is the required objective. A design for these trailers has been developed, and a prototype trailer has been fabricated and successfully static load tested and subjected to a short road test. This paper provides a summary of the trailer design development activity to date.

TRAILER DESIGN OBJECTIVES

GA is developing two LWT trailer designs to transport the PWR spent fuel (GA-4) and BWR spent fuel (GA-9) casks. The basic designs for these light-weight, high-integrity trailers are essentially identical except for small differences to account for the two cask designs. Envelope limits of 8 ft for the width, 43 ft for the length, and 13-1/2 ft for the loaded height of the trailer were specified. A design payload of 55,000 lb was established for the casks. The trailer, when hitched to the tractor fifth wheel, shall satisfy Federal Bridge Formula requirements. The center of gravity (CG) of the loaded trailer shall be as low as practical to maximize trailer stability.

Design, fabrication, and testing of these trailers is being accomplished using "American National Standard for Design, Fabrication and Maintenance of Semitrailers Employed in the Truck Transport of Weight-Concentration Radioactive Loads" [American National Standards Institute (ANSI) N14.30], complemented with additional requirements imposed by the program and GA. This is a new standard just issued in 1992. The principle structural requirement of this standard specifies that the trailer structural members be designed to withstand a static load of two and one-half times the sum of the live and dead loads without exceeding the minimum yield strength of the material(s). In addition, GA evaluated other trailer loading conditions involving combinations of longitudinal, lateral, torsional, and vertical loading. The allowable member stresses for these conditions were also limited to the material yield or buckling strength, whichever is less. GA also evaluated the trailer members for fatigue based on a design life of one million carriage miles.

TRAILER DESCRIPTION

The trailer design (Fig. 1) developed by GA with assistance from their trailer manufacturer, General Trailer Company in Springfield, Oregon, is a standard gooseneck single drop-deck trailer with cask trunnion supports. This type of trailer design was selected to keep the CG as low as possible. The achieved loaded CG is 6 ft 2 in. above the roadway, which is well below the ANSI N14.30 limit of 120% of the center-to-center width of the tire group (approximately 7 ft 2 in. for a typical 96-in.-wide trailer). The length of the GA-9 trailer is 42 ft 4 in. and the length of the GA-4 trailer is 41 ft 5-3/4 in., both within the 43-ft limit. The trailer designs permit the cask impact limiters to be removed while the casks are on the trailer. The casks can then be uprighted and removed from the trailer.

Meeting the target design weight of 9,000 lb, required a) the trailer material selected to be of a high strength/weight ratio, and b) the trailer main I-beams to be of a tapered design permitting weight optimization. The material selected for all load-bearing members is ASTM A514 (T-1 steel), a high-strength steel commonly used to fabricate industrial trailers.

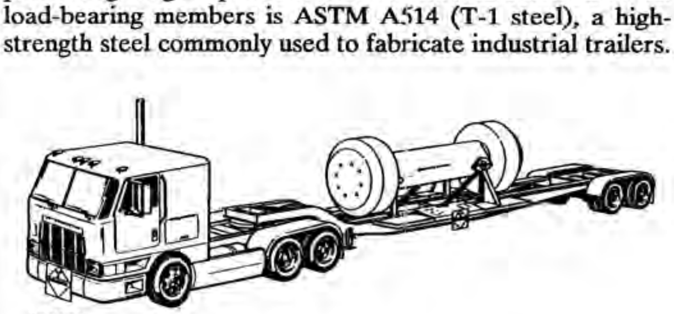
J-851(1)(b)
6-2-93

Fig. 1. Loaded tractor-trailer without personnel barrier.

This material has a yield strength of 100 ksi and an ultimate strength of 110 ksi. This material is sensitive to material quench and temper; therefore, fabrication by welding must be performed to strict qualified and controlled welding procedures. The trailer main I-beams are tapered sections providing strength where it is required. The compression flange is a channel section to provide the necessary a) stress distribution between the tension and compression flange to provide a balanced design, and b) buckling strength of the compression flange. The main beam web depth varies from 10-3/8 in. over the rear axles to 21-3/8 in. for the center portion, then down to 17-3/4 in. at the transition of the gooseneck. A rigorous finite element stress analysis of the trailers for all design conditions, combined with closely controlled fabrication, inspection, and testing, ensures the adequacy of the trailers.

An air-ride, self-leveling suspension system was selected for these trailers. Industry studies have determined that the dynamic characteristics of these suspension systems compared to spring suspension systems are advantageous from the standpoint of reduced shock and vibration loading during transport.

INITIAL TRAILER TEST

General Trailer Company completed fabrication and inspection of the first prototype GA-9 trailer early in December 1992. They performed a 2-g (110,000-lb) static load test of the trailer, per ANSI N14.30 requirements, on December 17, 1992. The trailer failed the test as a result of buckling of one of the main beams at the base of the gooseneck. The primary cause of the failure was overloading of a trailer main beam because of the way the test was conducted. The test was conducted a) on uneven terrain, b) with test weights (simulated cask plus a 44-in.-thick concrete block) with a high CG, and c) with the trailer tires and suspension supporting the test load. The combination of these factors caused rocking of the trailer. The rocking resulted from not being able to align the test weight CG with the trailer stiffness center. After trying to place the concrete block on the simulated cask approximately 10 times, the load was stabilized on the trailer using a tether line. One of the trailer's main beams web buckled at the gooseneck lower transition approximately 20 minutes after the load was stabilized. Secondary factors that contributed to the failure were a low margin of safety associated with web buckling at the gooseneck transition location and less than adequate test control because of the lack of detailed test procedures.

In spite of the trailer test failure being unexpected and a disappointment, it provided the trailer development activity an opportunity to greatly enhance the trailer design. Design enhancements at the trailer failure location resulted in a more balanced trailer design, further ensuring a safe and reliable trailer.

DESIGN MODIFICATIONS

Several design enhancements were made to the trailer design at the lower gooseneck transition region. They were: a) thickening the gooseneck beam web (1/4-in.-thick plate replacing 3/16-in.-thick plate) with web-to-web attachment welds remote from the gooseneck region, b) adding six radial stiffener plates to each beam at the lower gooseneck transition, c) increasing the length of the 3/8-in.-thick reinforcement plate on the compression flange at the gooseneck, and d) increasing the radius of curvature of the compression flange from 5-1/2 in. to 10 in. All of these changes resulted in a design greatly enhanced from that previously tested. The effects of curve beam conditions were reduced at this location and the beam web buckling strength was increased from the standpoint of both additional area and geometric stiffness.

During the initial static test, the trailer was observed to deflect laterally more than expected. The trailer design was modified to include some additional cross-bracing between the two trailer main beams. Stress analyses of the trailers confirmed this to be an effective means of increasing the lateral strength and stiffness of the trailer without increasing the trailer weight a significant amount.

SUBSEQUENT TESTS

The prototype trailer was modified to incorporate the design enhancements described above, and was subsequently retested under more favorable test conditions and with stricter test control. Changes in the way the test was conducted from the initial test were: a) the test was conducted on level ground, b) steel test weights were used on top of the dummy cask, keeping the test weight CG much lower than the initial test, and c) rigid supports were placed along the centerline of the rear tandem to support all loading in excess of the cask design weight of 55,000 lb. Strain gages were mounted on the trailer structure at locations of greatest concern. The readings from the strain gages were monitored during testing to ensure that stress conditions were consistent with predicted levels and to verify proper alignment of the test weights.

As a result of the precautions taken for the second 110,000-lb static test, no rocking of the trailer occurred during the placement of the test weights. The trailer remained loaded for the required full two hours with no observed problems. The strain gage results correlated very closely to predicted stresses, thus validating the trailer stress analysis. An inspection of the trailer after removal of the test weights revealed no significant problems. Minor cracks were discovered along the perimeter of some noncritical plug welds. It was determined that the cracks were caused as a result of weld shrinkage. These plug welds have been removed from the design as a result of an evaluation that determined they are not needed.

After the static test, a road test with the dummy payload (55,000 lb) in place was performed per ANSI N14.30 requirements. The GA-9 trailer was driven over a stretch of Interstate 5 from Springfield to Coburg, Oregon. The test route included 13 normal stops and starts on flats, inclines, and declines. The route also included seven right-hand and five left-hand 90-degree turns, one 180-degree reverse double superelevated cloverleaf onramp requiring a unique left- and right-hand turn, one straight ascending offramp, one descending onramp, and one ascending cloverleaf offramp. After completion of the dynamic road test, the trailer was inspected. The trailer passed the dynamic road test without incident.

ADDITIONAL PLANNED TESTING

The test plan for these high-integrity trailers requires the prototype trailer to be dynamically road tested. This test will determine the dynamic characteristics of the loaded trailer under anticipated road conditions and verify the adequacy of the trailer's endurance for a design life of one million miles. The first phase will encompass an equivalent 240,000 miles. The need for the remaining 760,000 equivalent miles will be determined after the first phase is complete. This accelerated durability test will be conducted at Allied Signal Automotive Proving Grounds over a test track that will simulate conditions anticipated for real-world conditions throughout the life of a trailer. The results of this durability test will be available later this year.

Subsequent to the durability test, the prototype trailer and tractor will be tested on highways transporting the dummy payload. Operability characteristics of the spent fuel transport system will be established from this final testing.

CONCLUSION

The spent fuel cask trailers designed by GA meet the high strength, low weight, and low center of gravity design requirements. Static load and dynamic road test results demonstrated that this trailer design satisfies the safety requirements. Final verification of the trailer design will be accomplished by the upcoming accelerated durability and operability tests.

ACKNOWLEDGMENTS

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