GA-4 Half-Scale Model Test*

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INTRODUCTION

General Atomics (GA), under contract to the U.S. Department of Energy (DOE),* developed two legal-weight truck shipping casks with trailers for transport of reactor spent fuel. The GA-4 and GA-9 casks were designed to transport four pressurized-water-reactor and nine boiling-water-reactor spent-fuel assemblies, respectively. GA has completed a half-scale model of the GA-4 cask, which was used for verification testing in support of the structural analysis presented in the Safety Analysis Report for Packaging (SARP). The objective of the test program was to verify the analyses of the 9-meter (30-foot) drop and 1-meter (40-inch) puncture event requirements set forth in 10 CFR Part 71.73.

HALF-SCALE MODEL CASK TEST ARTICLE

In order to verify the structural analyses for both the GA-4 and the GA-9 cask designs, a half-scale model of the GA-4 was constructed. The GA-4 and GA-9 designs are similar, but the GA-4 has slightly lower predicted stress margins for the containment boundary. A description of the cask designs and development can be found in the References. GA procured the cask model utilizing the coordinated efforts of three main subcontractors. Manufacturing Sciences Corporation (MSC), Oak Ridge, TN, supplied the five depleted uranium rings that form the gamma shield. The cask body, including assembly of the DU rings between the cavity liner and the outer shell, was manufactured by Precision Components Corporation (PCC), York, PA . Five scale model honeycomb impact limiters were fabricated by Lee Goebel Enterprises (LGE), Brea, CA. All significant features that might affect the structural performance during the regulatory drop and puncture events were modeled. The polypropylene neutron shield and outer stainless steel skin were modeled for mass only using stainless steel blocks welded to the outer shell. A removable fuel support structure was retained for the test model even though the GA-4 design was changed to be fully

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welded in place. The contents of the cask were a mix of steel and aluminum rods stacked in each fuel cavity to represent a distributed load across the fuel-support-structure cruciform wings.

TEST PLAN

GA prepared a test plan and detailed test procedures that specified three 9-meter drop test sequences: side drop, slapdown (see Fig. 1 below), and center of gravity (CG) over closure corner. These orientations envelop the most critical regulatory accident conditions. Each test sequence consisted of a 9-meter drop followed by one or more 1-meter puncture drops. The following is a short description of each test sequence.

Side-Drop Sequence

- Nine-meter drop with the cask oriented horizontally and a longitudinal edge of the cask facing the impact surface (the GA-4 has a square cross-section).
- One-meter puncture drop with the cask oriented horizontally and the punch striking the cask's structure adjacent to the corner of the closure's side.

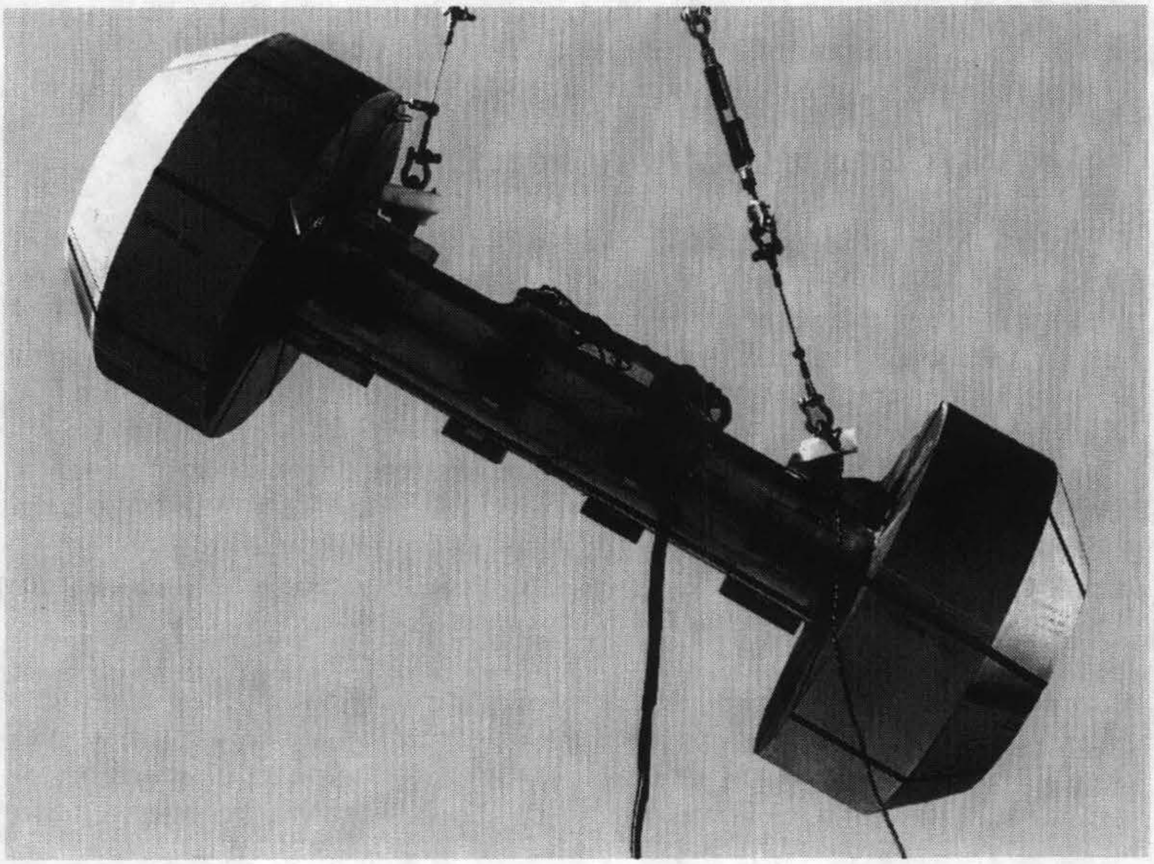

FIGURE 1. GA-4 HALF-SCALE MODEL CASK RIGGED FOR A 30° SLAPDOWN FROM A HEIGHT OF 9 METERS

Slapdown Sequence

- Nine-meter drop with the cask axis tilted 30 degrees from the horizontal position, the closure end striking first, and the flat side of the cask facing the impact surface.

- One-meter puncture drop with the cask oriented horizontally, the flat side facing the impact surface, and the punch striking the center of the cask body.

CG-Over-Closure-Corner Sequence

- Nine-meter CG-over-closure-corner drop with the cask axis tilted 12 degrees from the vertical position and a longitudinal edge of the cask facing the impact surface.

- One-meter puncture drop with the cask oriented 7 degrees from the vertical and the punch striking the closure in the vicinity of the gas sample port and closure bolts.

- One-meter puncture drop with the cask oriented horizontally with the punch striking a longitudinal edge of the cask body near mid-length at the location of a joint between two DU rings.

INSTRUMENTATION AND DATA ACQUISITION

The cask body was fitted with multiple strain gauges and accelerometers to measure the response of the model during the drop and puncture events. Strain gauges were located mid-length on the outer shell where the maximum deflection was expected. Accelerometers were mounted at each end of the outer shell as well as at mid-length. For the puncture tests, each 3-inch diameter steel spike was fitted with strain gauges in order to measure axial deflection of the spike and calculate the total load. Strain gauge and accelerometer leads were routed from the cask through a multiwire umbilical cable to a nearby "screen room" which contained all the signal conditioning, monitoring, and recording equipment. Gauge output was displayed on several Nicolet digital oscilloscopes and recorded on floppy disk and magnetic tape.

Two high-speed 16mm movie cameras (2,000 fps), one intermediate speed 16mm movie camera (400 fps), and several video camcorders were employed to record the drop events. Some additional video was taken of test preparations and post-test operations.

TESTING

Testing was conducted in San Diego, CA, at a facility operated by the S-Cubed Division of Maxwell Laboratories. GA constructed a concrete and steel drop pad which meets IAEA guidelines for an unyielding surface. S-Cubed provided technician and engineering support under contract to GA. All tests were performed at ambient temperature. The initial pressure in the cask fuel cavity was 0.55 mPa (80 psig). The cask was not disassembled or parts replaced during any test sequence. Impact limiters, impact limiter bolts, and closure seals were replaced after each sequence. For each drop, the cask was rigged in the proper orientation, lifted to a height of 9 meters (or 1 meter for the puncture tests) by a crane, and released by simultaneously firing several explosive cable cutters. Triggering the high-speed cameras, and the strain gauge and accelerometer data acquisition system was synchronized with the cable-cutter firing.

The closure O-ring seals and the gas sample port seals were leak tested before and after each test sequence. The impact limiters were inspected after each test to determine the damage caused by the test. Dimensional checks and helium leakage tests of the containment boundary and cavity liner were performed on the cask after all testing was completed.

RESULTS AND CONCLUSIONS

The performance of the GA-4 half-scale model met or exceeded all expectations. No permanent deformation of the cask body occurred except local dents from the puncture attacks. The cask held its full 0.55 mPa internal pressure and remained leaktight (air leakage less than 1.0×10^{-7} cm^3/sec) throughout all seven tests. All closure bolts remained torqued with no measurable deformation. The aluminum honeycomb impact limiters remained completely attached to the cask and crushed as expected, resulting in cask decelerations within the range of predicted values. The test results verify the structural analyses performed for the GA-4 and GA-9 cask designs and indicate that the new generation of legal weight spent fuel shipping casks will provide a high level of safety and greatly increased capacities compared to previous cask designs.

REFERENCES

GA-4 Legal Weight Truck From-Reactor Spent Fuel Shipping Cask , Final Design Report, General Atomics, San Diego, CA, GA Document No. 910353 N/C, 1995

GA-9 Legal Weight Truck From-Reactor Spent Fuel Shipping Cask , Final Design Report, General Atomics, San Diego, CA, GA Document No. 910354 N/C, 1995