Fabrication and Acceptance Testing of the Half-Scale Model GA-4 Legal-Weight Truck Cask*

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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 are designed to transport four pressurized-water-reactor and nine boiling-water-reactor spent-fuel assemblies, respectively. A description of the cask designs and development can be found in the References. In 1995 GA completed a half-scale model of the GA-4 cask, which was recently used for verification testing in support of the structural analysis presented in the Safety Analysis Report for Packaging (SARP).

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 (Fig. 1) was manufactured by Precision Components Corporation (PCC), York, PA, including assembly of the DU rings between the cavity liner and the outer shell. Five scale model honeycomb impact limiters were produced 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. During the course of fabrication, special processes were developed and valuable lessons were learned that can be applied to full-scale prototype and production cask units manufactured in the future.

DU GAMMA SHIELD

The gamma shield consists of five noncircular "rings" of depleted uranium (DU) each weighing about 295 kg (650 lb). The gamma shield was considered to be a "long lead" component, and procurement was begun in advance of the other cask

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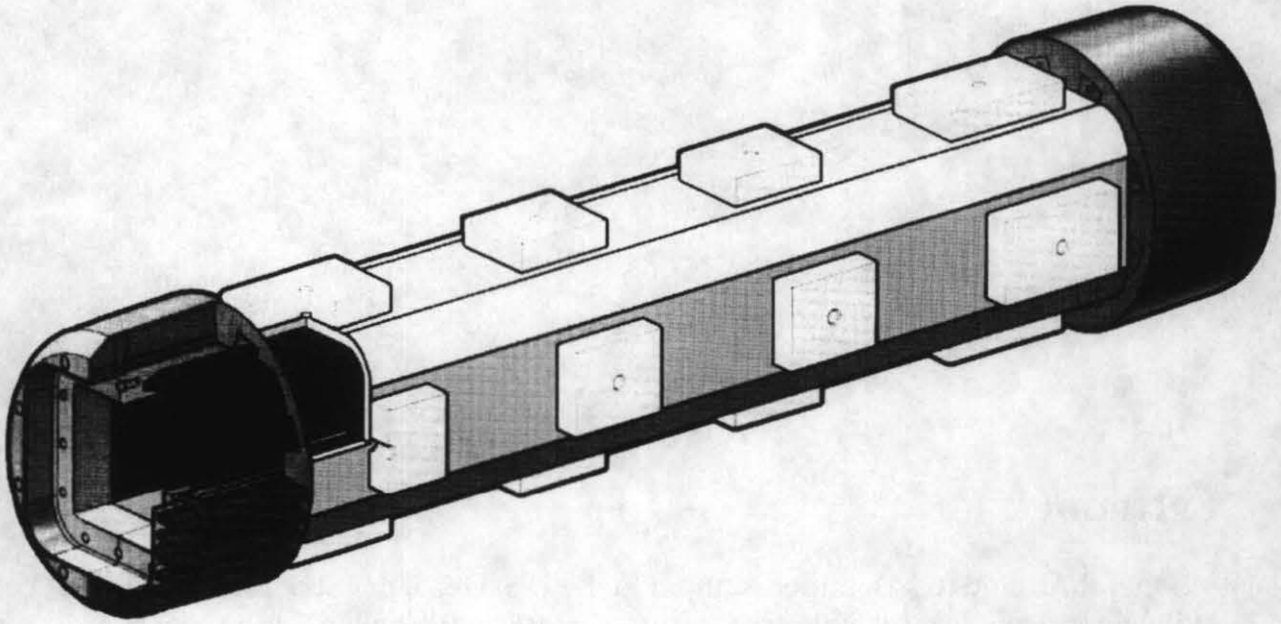

FIGURE 1. GA-4 HALF-SCALE MODEL CASK (SHOWN WITHOUT IMPACT LIMITERS)

components. After soliciting competitive bids, GA selected MSC to supply the DU rings. The rings were vacuum cast and machined to size by conventional milling and planing techniques. Some customized tooling was required to permit machining of the inner surfaces to the relatively tight tolerances specified, ±.13 mm (±.005 in.). The successful machining operations proved that more exotic and costly techniques such as electro-discharge machining were not necessary to achieve the desired inside surface profile. The DU rings were inspected and gamma scanned before acceptance by GA.

CASK BODY AND CLOSURE

The primary structural material for the GA-4 cask is XM-19, a nitrogen-fortified austenitic stainless steel chosen for its 379 kPa (55 ksi) yield strength (versus 207 kPa (30 ksi) for type 304 stainless steel. The experience gained in forming, welding, and machining this material during the production of the various cask components showed that its behavior is significantly different from the 300 series stainless steel. A material failure during cold forming of the cask outer shell led to the development of a hot-forming procedure to produce the shell halves. Efforts to qualify procedures for gas metal arc welding (GMAW) were successful only after the XM-19 weld filler material used in the gas tungsten arc welding (GTAW) process was replaced by Inconel 625 filler material. Actual machining times for the major components greatly exceeded original estimates due to the tendency of the material to distort unless the material removal rate was much less than is typical for 300 series stainless steel.

Since the cask body and cavity liner have a noncircular cross section, the interior surfaces are difficult to machine. The manufacturing approach was to finish machine these components in halves and then join the halves together using low-distortion welding techniques. Both laser and electron beam (EB) welding processes were studied during the preproduction development phase of fabrication. EB welding proved to be more suited to the material, and this process was chosen for the long seam joints on the liner and outer shell. EB welding was also employed on the fuel support structure when weld mockups using GTAW resulted in unacceptable distortion.

IMPACT LIMITERS

The model employs two aluminum honeycomb impact limiters, one at each end of the cask to limit deceleration rates during the three planned 9-meter drop events. Five impact limiters were built so that undamaged units could be used for the 9-meter side drop and the 30° slapdown. For the CG-over-corner-end drop, it was planned to use a damaged unit for the upper end limiter. The honeycomb for each impact limiter was bonded in segments to an XM-19 housing that is bolted to the cask (Fig. 2).

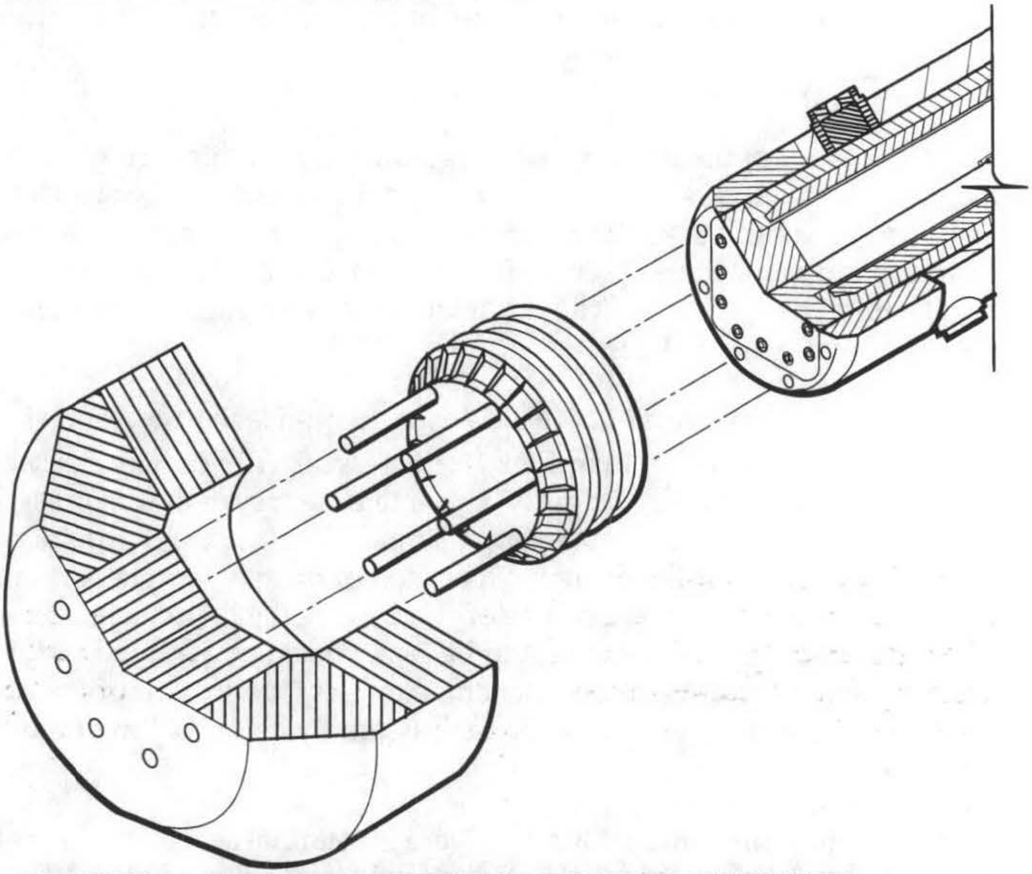

FIGURE 2. BONDED HONEYCOMB IMPACT LIMITERS ARE BOLTED TO EACH END OF THE CASK

Controlling weld distortion during the fabrication of the housings proved to be difficult due to the thin 3 mm (0.125 in.) stock size and the relatively large amount of welding that was required. The first housing unit produced had a number of deviations which made necessary some custom fitting of the honeycomb in order to achieve a successful adhesive bond. For subsequent units, the fabricator agreed to employ additional tooling and fixtures to maintain better dimensional control. Although the remaining housings showed an improvement in quality, they also had deviations which required custom fitting of the honeycomb.

Difficulties were encountered with the five-axis milling machine during final machining of the honeycomb subassembly prior to outer skin bonding. When programmed to cut the desired contour on the part, interference between the part and the spindle and also between the spindle and the machine bed occurred. Two specially designed milling cutters and some customized fixtures had to be fabricated in order to successfully complete final machining.

Prior development work associated with one-quarter scale impact limiter testing showed that the stainless steel outer skins required a rough ground finish in order to achieve a good adhesive bond with the honeycomb. After several unsuccessful attempts at grinding the skin, LGE located a vendor that was able to surface roughen the skin without distorting it. The skins were laser cut to size and bonded to the honeycomb with the aid of a vacuum bagging technique that maintained uniform external pressure during the elevated temperature cure.

ACCEPTANCE TESTING

Before delivery of the five depleted uranium gamma shield rings to PCC for assembly into the cask body, MSC and its subcontractor MQS Inspection, Inc. conducted a complete gamma scan of each ring. The gamma scan results were compared to scans of test pieces of void-free DU - .2% Mo alloy (19.00 gm/cc minimum density) and indicated a shielding effectiveness equivalent to 100% of the minimum wall thickness.

The containment boundary of the cask was helium leak tested and shown to be leak tight (leakage of less than 1.0×10^{-7} cm^3/sec). The cavity liner was also tested and found to be leak tight. The containment system was pressure tested at 827 kPa (120 psig), which represents 1.5 times the maximum normal operating pressure (MNOP) for the design. Operation of the gas sample port and helium fill ports was verified in the course of conducting the helium leakage tests. PCC demonstrated that the closure could be easily installed with the cask in either a horizontal or vertical position. General Atomics Quality Control performed a final dimensional inspection of the cask assembly before shipment to San Diego, California.

The five honeycomb impact limiters were given final acceptance after a review of LGE's inspection records and a functional test witnessed by GA Quality Assurance in which each limiter was shown to fit over a plug gauge that was machined to represent the maximum material condition of the cask ends. The plug gauge was previously used to verify the inside diameter of the impact limiter housings prior to honeycomb bonding.

CONCLUSIONS

Fabrication of the GA-4 half-scale model cask proved to be a challenging undertaking due to the lack of an established data base of experience in welding, forming, and machining XM-19 stainless steel. This necessitated the development of processes and parameters specifically for this project. The tight tolerances and relatively thin gauge material for some components also contributed to the difficulties. However, many of the techniques developed for this model will be directly applicable to full-scale prototype and production units.

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.