NEW GENERATION LEGAL WEIGHT SPENT FUEL SHIPPING CASK

R. J. Meyer and D. M. Osborne
GA Technologies Inc.
San Diego, California 92138

ABSTRACT

GA Technologies has proposed two new spent fuel shipping casks that have a capacity four times greater than comparable existing designs. The new casks, for legal weight truck shipments, will carry four PWR or nine BWR spent fuel assemblies. They were offered in response to the recent request for proposals issued by the Office of Civilian Radioactive Waste Management (OCRWM). The RFP addressed a new generation of truck and rail shipping casks that could transport intact spent fuel assemblies from nuclear reactors to a respository or a Monitored Retrievable Storage (MRS) facility. Our primary goal has been to maximize the number of fuel elements of each fuel type that a LWT cask can carry, while ensuring that the design meets all licensing requirements.

TWO OPTIMIZED CASK DESIGNS MAXIMIZE CAPACITY

GA's technical approach for the From-Reactor LWT casks is to develop two optimized designs, one for PWR and one for BWR fuel, that meet all performance specifications with minimum certification risk and maximum payload capacity. A single cask, capable of carrying both BWR and PWR fuel, would be much less efficient because the configuration would have to combine the shielding necessary for the PWR fuel with the added length to accommodate BWR fuel. Our conclusion was that such a configuration could not carry four PWR or nine BWR elements and achieve a gross vehicle weight (GVW) less than 80,000 lbs.

GA's two-optimized design approach gives the greatest benefit to the OCRWM program because maximizing payload minimizes life cycle costs, reduces transportation risks by reducing the number of shipments, and provides the greatest ALARA (as low as reasonably achievable dose) benefits. We based our designs on our analyses of dimensional, structural, shielding, and criticality requirements for casks that could most efficiently carry each of these fuel types.

Existing legal weight truck (LWT) casks were designed to accommodate relatively short-term cooled fuel and, therefore, the shielding and heat rejection requirements limited their capacity to one PWR or two BWR fuel assemblies. The new generation of casks will be designed to accommodate fuel that has been out of the core for ten years.

CASK CAPACITY BASED ON OPTIMUM, YET REALISTIC TRANSPORTER WEIGHTS

GA recognized the opportunity to achieve a fourfold increase in the capacity of a legal weight truck cask by the application of innovative weight saving techniques to the cask and transporter. The target weight goals are 25,000 lbs. for the transporter and 54,000 lbs. for the loaded cask.

As shown in Fig. 1, the transporter will be a 5 axle tractor-semitrailer combination consisting of a 16,000 lb. tractor and a 9,000 lb. semitrailer. The tractor weight is realistic and is based on existing lightweight vehicles on the road today. Modern tractors currently make extensive use of lightweight materials in the cab and frame. Without major reductions in the weight of the heavy drivetrain components, we do not foresee major reductions in the tractor weight. GA has recommended that DOE explore the benefits to the OCRWM program of development of an ultra-lightweight tractor.

For the semitrailer, GA will maximize the use of lightweight materials. We will perform detailed structural and fatigue analyses to develop a design to minimize weight.

CASK DESIGN

We began our design process by developing design criteria that ensures compliance with the specified performance requirements. We performed conceptual trade-off studies to establish the most efficient cask cross section geometry, the optimum amounts and materials for gamma and neutron shielding, and the thicknesses and sizes of structural components. We based our designs on preliminary structural, thermal, shielding, criticality, and weight analyses.

GA's optimized concepts comply with DOE-ID's specifications, commercial codes and standards, such as Sections II, III, and IX of the ASME Boiler and Pressure Vessel Code, and regulatory requirements. We perform our design, analysis, testing, and fabrication under our NRC-approved QA program.

Cask Body

Figure 2 shows the features common to both casks. GA's design uses austenitic stainless steel for the structural components of the pressure vessel wall. Stainless steel is an excellent material for a spent fuel shipping cask as it has an inherent margin of safety above that of carbon steel or cask iron: it will deform far beyond the elastic analysis limits established in Regulatory Guide 7.6 before rupturing, and it is a ductile material at temperatures far

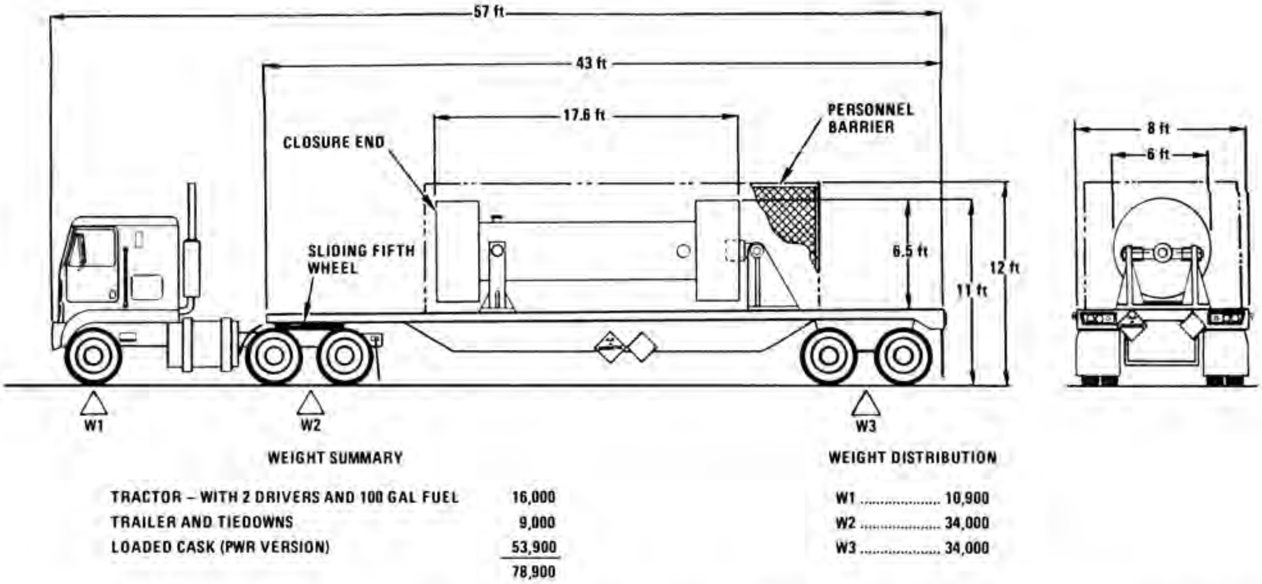

Fig. 1. GA's PWR LWT Cask Axle Loadings and Weight Distribution Meet State Requirements and Comply With the Federal Bridge Formula.

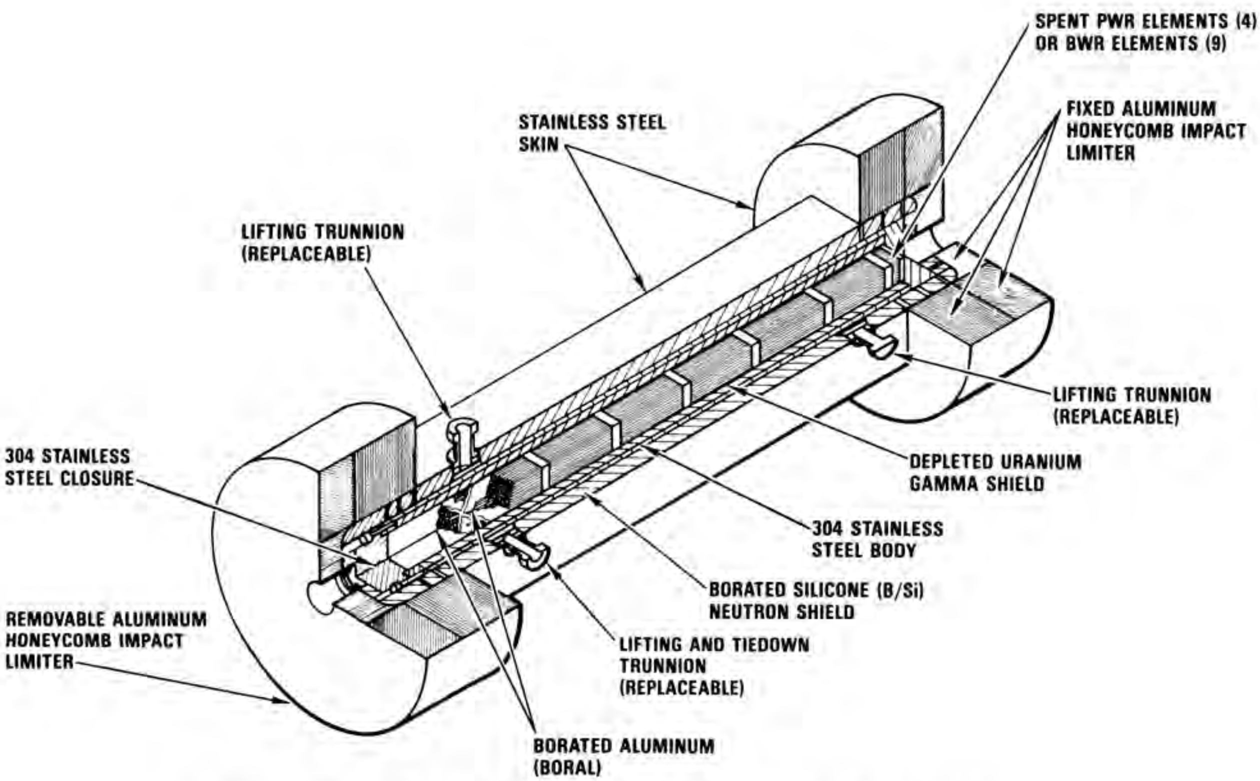

Fig. 2. GA's LWT Casks Maximize Payload Capacity for Each Fuel Type.

lower than those encountered in truck transport which ensures that brittle fractures will not occur.

Directly inboard of the stainless steel cask wall is a layer of depleted uranium (DU) plate which, along with the cask wall and borated silicone, provides sufficient shielding to limit the dose rate to comply with transportation regulations. We have further minimized weight by putting the most dense materials toward the inside of the cask. Working outword from the fuel, we have DU, stainless steel, and borated silicone neutron shielding. This arrangement gives the required strength and shielding with minimum weight and maximum payload.

Figure 3 shows a cross section of the PWR cask and Fig. 4 shows the BWR version. The cross sections of the casks are shaped to closely fit around the fuel elements and minimize weight. We found that the shaped design with rounded corners weighs about 3,000 lbs. less than a round design with the same capacity. Our four- and nine-element designs meet the LWT limit because of this feature. The rounded corners are sized to prevent excessive stress concentrations. All external cask surfaces which will be exposed to fuel pool water are smooth stainless steel to ensure ease of decontamination.

Shielding thicknesses and criticality control are optimized for each type of cask. The shielding is tapered in the nonfuel region to minimize weight. Removable fuel assembly baskets are constructed of borated aluminum (Boral) sandwiched between stainless steel plates to provide criticality control.

Closure

Solid stainless steel bolted closures are used on both casks. Our design has elastomeric 0-ring seals that will be leak tested prior to each shipment. We will specify a rubber compound, such as silicone, that is appropriate for sealing at both -40°C (-40° F) and at the maximum seal temperature encountered during the hypothetical accident condition.

GA has recommended to DOE that a nonbolted, quick-acting closure be developed in parallel with the new generation of casks to reduce exposure time of operating personnel. Several quick-acting mechanisms have been studied in the past by GA and others, and we believe that potential savings in operation time and ALARA benefits should be identified and evaluated as part of the overall cask design program.

Impact Limiters

As shown in Fig. 2, the GA From-Reactor LWT cask has external impact limiters made of stainless steel and aluminum honeycomb. We selected these materials because they have constant and predictable properties over the design temperature range. They are more efficient than the traditional wood and foam materials, but are not combustible and, therefore, pose a lower risk to the seals in a fire accident. We believe that noncombustible materials should be used, if available, for external safety components on a nuclear shipping cask.

The bottom impact limiter is permanently attached to the cask and is not removed during cask handling or spent fuel loading/unloading operations. A cask with fixed honeycomb impact limiters has several distinct advantages over removable foam or wood limiters:

- Protection of the cask during all handling operations as well as during transport,
- Significant reduction in operation and handling time,
- Increased stability in the vertical position,
- No degradation of energy absorption capability over time, and
- The limiters more securely anchored to the cask by welding and, therefore, are less likely to be knocked off in an accident.

Trunnions

There are four replaceable lifting trunnions, at 90° locations, on the closure end of the cask. Two of these trunnions are also used for securing the cask to its transporter. Two additional replaceable trunnions located near the bottom end of the cask provide horizontal lifting capability.

Shielding and Criticality Control

The GA From-Reactor LWT Cask uses DU for gamma radiation shielding because it absorbs the greatest number of gammas per pound of cask weight. Since DU is a relatively brittle material, little used for structural applications, we will not rely on it to withstand structural loads during the hypothetical accident condition tests. GA will use its experience gained by designing, fabricating, obtaining an NRC Certificate of Compliance for, and operating the FSV-1 LWT cask, which also has DU shielding.

For neutron shielding, we have specified solid borated silicone. This material is a resilient, self-supporting solid which has a hydrogen content equal to 2/3 that of pure water. Hydrogen provides the most effective shielding for fast neutrons. Borated silicone is self-extinguishing and will withstand temperatures up to 204°C (400°) continuously. A 1.0-percent by weight boron content aids in capturing thermal neutrons and reducing capture gamma radiation. Other neutron shielding materials, such as borated polyethylene, have a somewhat higher hydrogen content, but have poor temperature

resistance. Borated silicone exhibits the best combination of effective neutron shielding and temperature resistance. It is castable in place, which eases fabrication and enables forming to any desired shape.

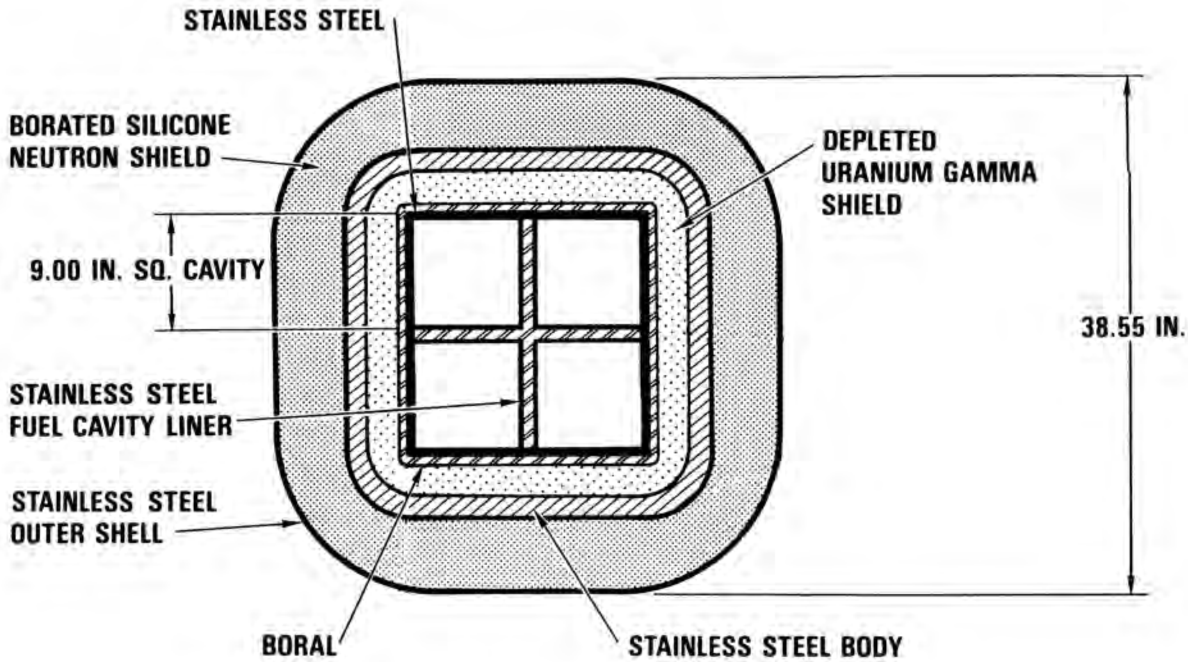

Fig. 3. GA's LWT Cask Carries 4 PWR Elements.

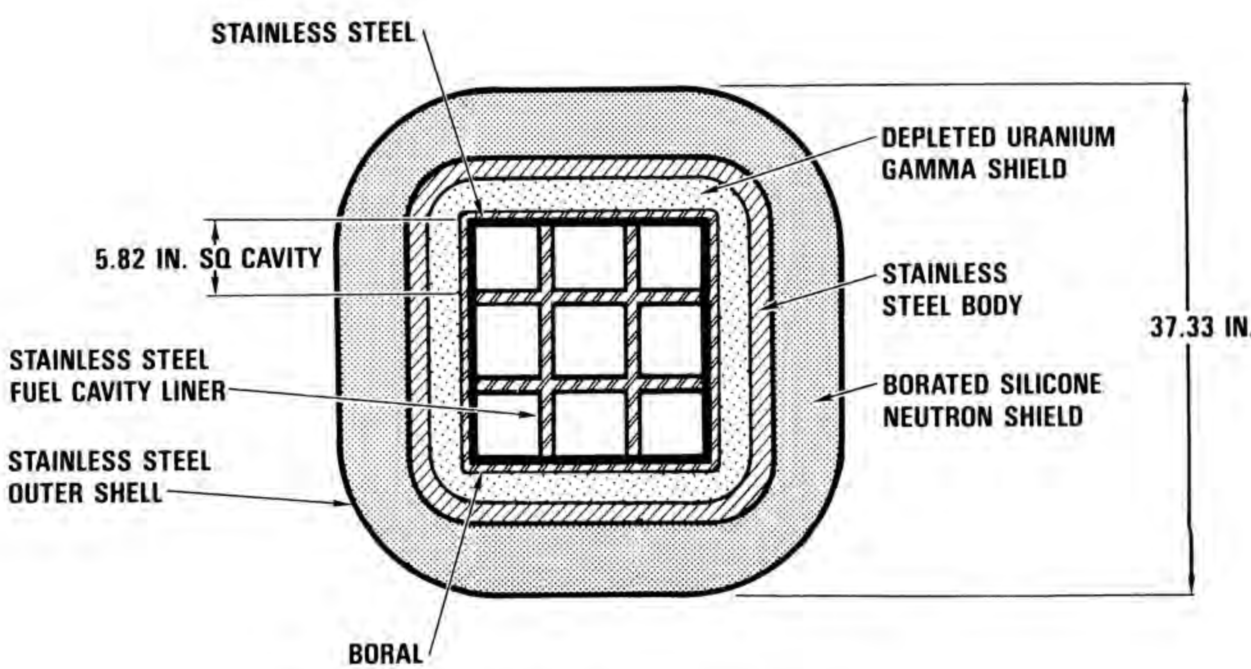

Fig. 4. GA's LWT Cask Carries 9 BWR Elements.

Boron carbide, encased in aluminum sheets (Boral), is specified for use in the cavity liner and fuel basket to control criticality. The Boral is sandwiched between austenitic steel plates and is used to separate the spent fuel elements.

DESIGNED FOR LOW LICENSING RISK

While achieving a legal weight truck cask with a capability of four PWR or nine BWR fuel assemblies is an ambitious engineering goal, the licensing risk is low. GA's design for the From-Reactor LWT cask minimizes certification risk by using well characterized and proven materials for the containment boundary, shielding, seals, and energy absorbing devices; by developing, early in the design process, a certification plan that identifies issues and plans their resolution; and by following the structural design criteria given in Regulatory Guides 7.6 and 7.8, applicable sections of the ASME Boiler and Pressure Vessel Code, and leak tightness criteria of ANSI N14.5.

The structural integrity will be proven by analysis and by a combination of engineering tests, scale model tests, and, possibly, full-scale prototype tests. Criticality control and shielding adequacy will be demonstrated analytically with NRC approved methods. Uncertainties about a quick-acting closure will not affect initial NRC licensing since each cask will be submitted for approval with the bolted closure. The quick-acting closure, if proven adequate, will be covered by an amendment to the SARP.

ALARA AND LIFE CYCLE BENEFITS

We believe that maximizing payload has the greatest ALARA and life cycle cost benefits. By reducing the number of shipments through increased payload, our design minimizes both (a) operations personnel and public exposure and (b) the probabiliity of accident events.

The greatest single factor in life cycle costs is the number of shipments. Maximizing payload, therefore, minimizes overall life cycle costs. In addition, maximizing payload reduces fleet costs because the number of casks required is reduced. For example, we participated in a value analysis of a cask design (1) which concluded that 86% of the total life cycle costs were associated with the number of trips and handling operations. The value analysis teams found that increases in payload capacity produced nearly proportional reductions in total life cycle costs.

To further optimize ALARA and life cycle cost considerations, GA will design the LWT casks to minimize the number of handling operations required and will incorporate quick-acting features in the design to minimize operating times. We will also make all operational features compatible with remotely-automated operations to minimize turnaround time. Minimizing turnaround time not only minimizes life cycle labor costs, but also reduces capital costs through reduced fleet requirements.

SUMMARY

In summary, the development of high capacity legal weight truck shipping casks for PWR and BWR fuel assemblies will provide flexibility and efficiency to the From-Reactor Cask program while minimizing the licensing risk. GA's design will be augmented through the use of a comprehensive test program and well proven materials and analytical methods.

REFERENCES

1. Final report of the TRUPACT Value Analysis Task Force, submitted to DOE-AL, May 15, 1985.