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# GA-4 and GA-9 Legal Weight Truck Shipping Cask Development

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## INTRODUCTION

General Atomics (GA), under contract to the Idaho Operations Office of the U.S. Department of Energy, is developing two new legal weight truck spent fuel shipping casks that will carry four PWR or nine BWR spent fuel assemblies. They are being developed for the Office of Civilian Radioactive Waste Management (OCRWM) to meet its mission to dispose of nuclear wastes at a permanent disposal site. Our primary goal is to maximize the number of fuel elements of each fuel type that a LWT cask can carry, while ensuring that the design meets all NRC licensing requirements.

### Separate PWR and BWR Cask Designs Minimize Total Life-Cycle System Costs

GA's technical approach for the From-Reactor legal weight truck 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 carry only two or three PWR elements and five or six BWR elements because the configuration would have to combine the shielding necessary for the PWR fuel with the added length to accommodate BWR fuel. Our design approach is to develop configurations that carry four PWR or nine BWR elements and achieve a gross vehicle weight (GVW) less than 80,000 lbs. We call the PWR version the GA-4 cask and the BWR version the GA-9 cask.

The 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. GA is presently nearing completion of the preliminary

design phase and has completed analyses of dimensional, structural, shielding, thermal and criticality requirements for the GA-4 and GA-9 casks.

Existing 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 GA-4 and GA-9 casks are designed to accommodate fuel with the following characteristics:

	PWR	BWR
Fuel Age	10 Years	10 Years
Initial Enrichment Range	3 to 4.5%	3 to 4.5%
Burnup Range	18,000 to 35,000 MWD/MTU	15,000 to 30,000 MWD/MTU

#### Development of Efficient Transport Vehicles

GA recognized the opportunity to achieve a fourfold increase in the capacity of a legal weight truck cask by the application of weight saving techniques to the cask and transporter as an integrated system. The target weight goals are 25,000 lbs for the transporter and 54,000 lbs for the loaded cask. The present cask weights are 53,800 lbs and 53,900 lbs.

Figure 1 shows that the transporter will be a 5-axle tractor-semitrailer combination consisting of a 16,000 lb tractor and a 9,000 lb semi-trailer. The tractor weight is realistic and is based on existing vehicles on the road today. Modern tractors currently make extensive use of efficient, lightweight materials in the cab and frame. GA has recommended that DOE explore the benefits to the OCRWM program of sponsoring the development of a more efficient, lightweight tractor for the future.

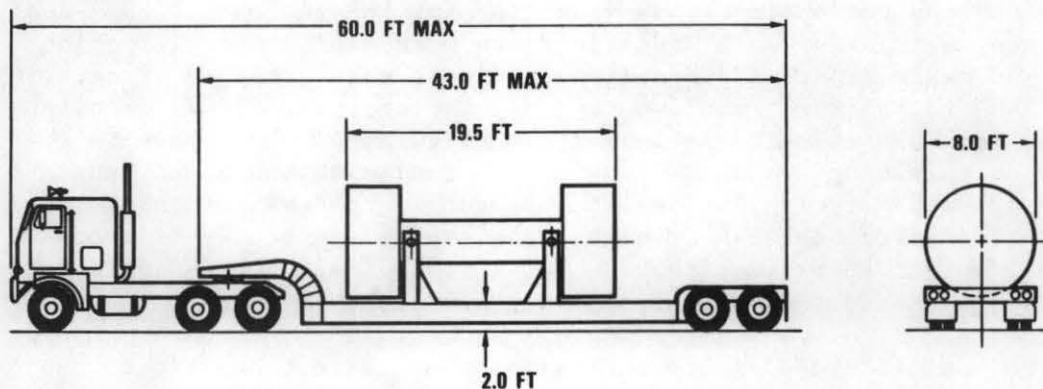


Figure 1. The GA-4 and GA-9 Legal Weight Truck Casks Meet State Requirements for Axle Loading and Weight Distribution and Comply with the Federal Bridge Formula

GA has begun a program to work with a trailer manufacturer to develop a premium quality, high capacity semitrailer for the GA-4 and GA-9 casks. A semitrailer performance criteria document was completed and used as a basis for a request for quotation from qualified trailer manufacturers, one of which will be awarded a subcontract to design and fabricate a prototype semitrailer. GA will perform detailed analyses of the trailer structure and subject a prototype to development testing to qualify the design.

### Preliminary Design Nearly Complete

We began our design process by developing design criteria that ensure 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 the GA-4 and GA-9 cask designs on preliminary structural, thermal, shielding, critical and weight analyses.

The designs 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 which complies with ANSI/ASME NQA-1 1986.

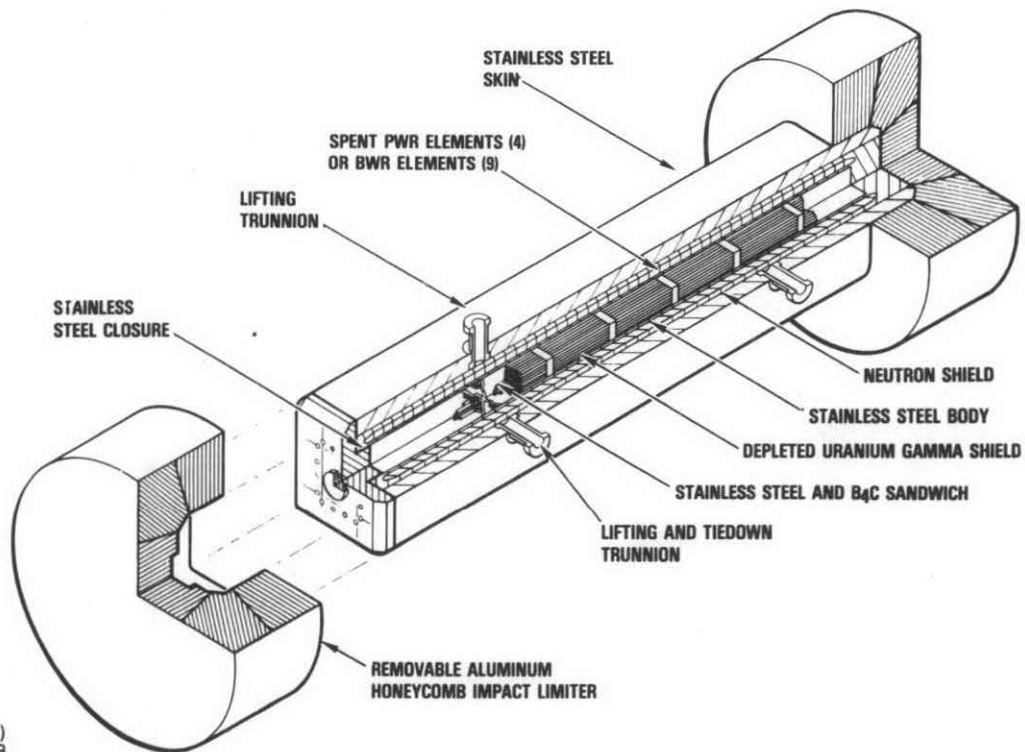


Figure 2. GA-4/GA-9 Legal Weight Truck Spent Fuel Shipping Cask

## Cask Body

Figure 2 shows the features common to both casks. GA's designs use Type XM-19 austenitic stainless steel for the structural components of the pressure vessel wall. Type XM-19 stainless steel is an excellent material for a spent fuel shipping cask as it is relatively high strength and has an inherent margin of safety above that of carbon steel or cast iron. It will deform far beyond the elastic analysis limits established in USNRC Regulatory Guide 7.6 before rupturing, and is a ductile material at temperatures far 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 a solid neutron shield, 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 outward from the fuel, we have DU, stainless steel and solid 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 weights about 3,000 lbs less than a round design with the same capacity. Our four- and nine-element designs meet the LWT limit of 80,000 lbs because of this feature. We analyzed the

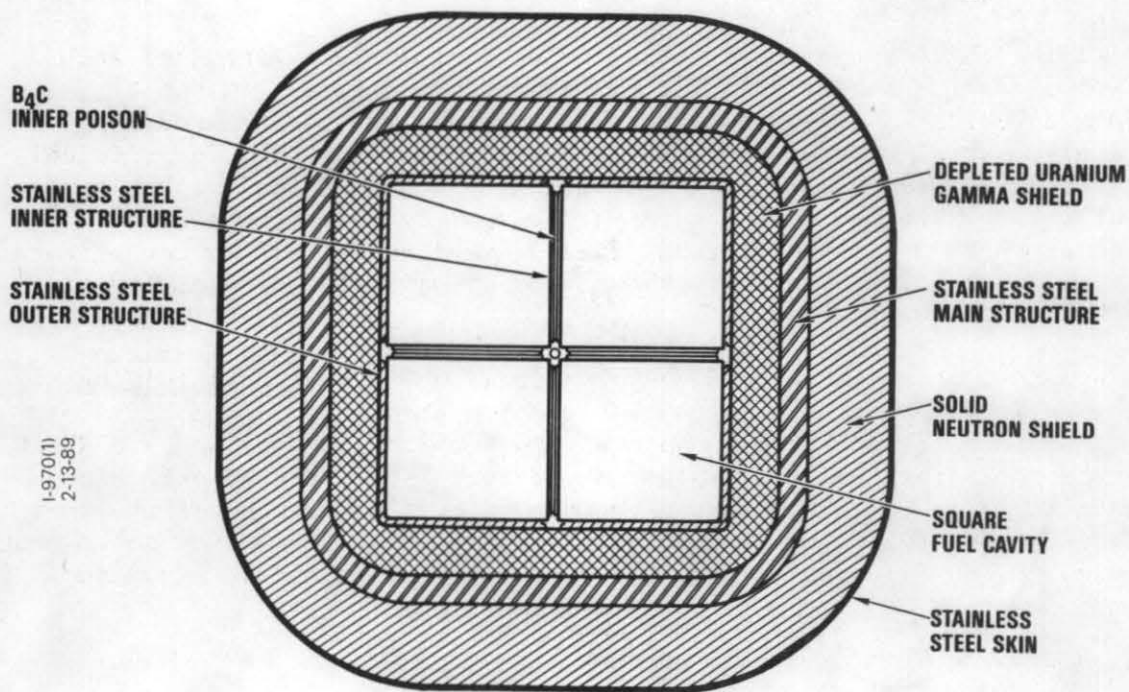
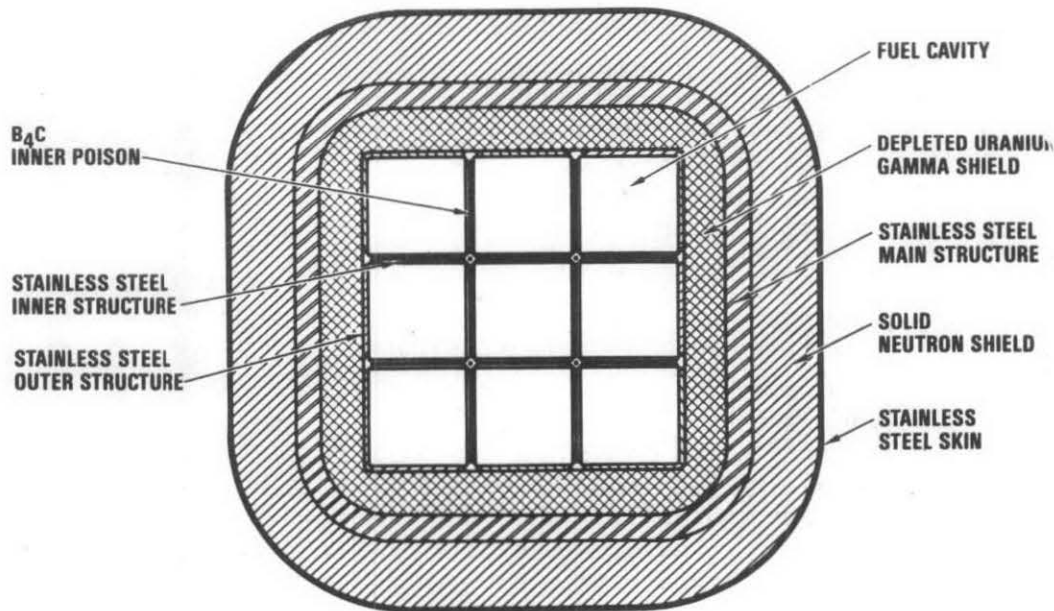


Figure 3. GA-4 Cask Maximizes Payload for Legal Weight Truck Shipments of PWR Fuel



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**Figure 4. GA-9 Legal Weight Truck Cask Maximizes BWR Spent Fuel Payload**

cask body using finite element techniques and sized the rounded corners to prevent excessive bending stresses. 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 regions to minimize weight. Fixed fuel assembly supports are constructed of stainless steel plates which surround boron carbide,  $B_4C$ , for criticality control. We are currently evaluating a removable fuel basket option that will enable the GA-4 and GA-9 to accommodate additional fuel types such as certain limited-quantity fuel assemblies as well as consolidated fuel. The primary objective, though, is to maintain the capacity of 4 PWR or 9 BWR elements.

We are testing three commercially available solid neutron shielding materials that provide the greatest neutron absorbing capabilities per unit weight. These materials are RX-201-1 boron polyethylene and RX-207 borated polyethylene from Reactor Experiments, Inc. and NS-4-FR fire resistant shielding from Bisco Products, Inc. The purpose of the test is to demonstrate that these materials do not provide an additional heat source to the vulnerable seal area during the hypothetical accident condition fire test.

#### Closure

Solid stainless steel bolted closures are used on both casks. Our designs have elastomeric O-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  $-40^{\circ}\text{C}$  ( $-40^{\circ}\text{F}$ ) and at the maximum seal temperature encountered during the hypothetical accident condition.

Our preliminary designs use eight 1-inch bolts and twelve 1-3/8-inch shear pins to attach the closures to the cask body. The shear pins are sized to transmit lateral loads and limit bending of the closure bolts.

### **Impact Limiters**

Figure 2 shows the GA-4 and GA-9 casks' external impact limiters which are made of aluminum sheet and honeycomb. We selected these materials because they have constant and predictable properties over the design temperature range. They are more weight 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 are fabricating and testing scale model impact limiters to ensure that we can characterize their force-vs.-deflection behavior over the range of impact orientations.

### **Trunnions**

There are four replaceable lifting trunnions, at  $90^{\circ}$  locations on the closure end of the cask. We have sized the trunnions to accommodate a non-redundant lifting system in accordance with NUREG 0612. Our cask lifting yoke will also meet the requirements for non-redundant lifting. 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-4 and GA-9 casks use 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 has designed, fabricated and obtained an NRC Certificate of Compliance for the FSV-1 cask which also has DU shielding.

We have completed a screening test program aimed at selection of the most weight-efficient neutron shield material that does not jeopardize the integrity of the packaging during a hypothetical accident condition fire event. As a result of these tests, we changed from borated silicone to one of three other materials that we are testing in a fire environment. These materials are commercial products, two of which are sold by Reactor Experiments, Inc. (RX-201-1 and RX-207), and NS-4-FR from Bisco Products, Inc. These materials are the most weight efficient and did not continue to combust after exposure to  $800^{\circ}\text{C}$  for 30 minutes.

We use pressed boron carbide plates ( $\text{B}_4\text{C}$ ) for criticality control as  $\text{B}_4\text{C}$  has the greatest content of boron per pound of material. The GA-4 will rely on burnup credit to achieve the required degree of criticality

safety. The GA-9 cask will not rely on burnup credit because there is no weight saving to be gained.

#### **Designed for Low Licensing Risk**

While achieving a legal weight truck cask with a capability of four PWR or nine BWR assemblies is an ambitious engineering goal, the licensing risk is low. The GA-4 and GA-9 casks minimize 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 USNRC 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 and half-scale model tests. Criticality control and shielding adequacy will be demonstrated analytically with NRC-approved methods.

#### **ALARA and Life-Cycle Cost 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 designs minimize both operational personnel and public exposure and the probability 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. Our experience indicates that increases in payload capacity is nearly proportional to reductions in total life-cycle costs. To further optimize ALARA and life-cycle cost considerations, GA is designing the GA-4 and GA-9 casks to minimize the number of handling operations required and is incorporating quick-acting features in the design to minimize operating and exposure times. We are also making 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 the GA-4 and GA-9 LWT shipping casks for PWR and BWR fuel assemblies provides flexibility and efficiency to the From-Reactor Cask Program while minimizing the licensing risk. We have based these designs on proven materials and analytical methods and are verifying their performance through a comprehensive test program.

#### **Acknowledgments**

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