SHIELDING DESIGN FOR SPENT FUEL SHIPPING IN HIGH-CAPACITY TRUCK CASKS

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General Atomics (GA), under contract to the U. S. Department of Energy (DOE), is developing a high-capacity legal weight truck transportation system for shipment of pressurized-water-reactor (PWR) and boiling-water-reactor (BWR) spent fuels from commercial nuclear power plants to a repository or monitored retrievable storage facility. The system includes two cask versions optimized for PWR and BWR fuels, respectively. The PWR version carries four fuel assemblies designated the GA-4 cask; and the BWR version accommodates nine fuel assemblies designated the GA-9 cask. This paper presents the shielding aspects of the GA-4 and GA-9 casks.

Our approach to shielding design is to optimize the cask shielding configurations for minimum weights and maximum

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payloads. The optimization methods involve use of the most effective shielding materials, square cross-section geometry with rounded corners and tapered shielding sections in the non-fuel regions. In addition, the trade-off between the neutron and gamma shield thicknesses enables selection of an optimum design where the cask weight is at a minimum.

Shielding design assumes a typical fuel burnup of 35,000 GWd/MTU for PWR fuels and 30,000 GWd/MTU for BWR fuels. Both PWR and BWR fuel assemblies have cooled 10 years. The lower burnup for BWR fuels results in a lower radiation source strength and less shielding required for the GA-9 cask. We obtained neutron and gamma source data from the computerized data base[1] developed by Oak Ridge National Laboratory for the DOE. The data include both active fuel and hardware components.

The GA-4 and GA-9 casks feature compatible shielding designs. Both casks are optimized for maximum payloads with similar shielding configurations using the same shielding materials. Figure 1 shows the cross section of each cask. The main body (i. e. sidewall) of each cask uses a combination of depleted uranium (DU) and stainless steel primarily for gamma shielding, and solid boron polyethylene

as a neutron shielding. Optimum amounts and thicknesses of neutron and gamma shielding with the most dense material placed toward the inside of the cask are provided to achieve the most efficient cask geometry. For simplicity in design and ease of fabrication, the top and bottom ends of the cask use a solid stainless steel structure which provides sufficient shielding for neutrons and gammas.

We performed shielding analyses for the GA-4 and GA-9 casks with a variety of advanced computer codes. The bulk neutron shield was sized with 1-D ONEDANT transport code[2]; and the bulk gamma shield was determined with the 3-D PATH point-kernel code[3]. The 3-D MCNP Monte Carlo code[4] was used to verify shielding adequacy of the complete cask including analyses of corner effects, secondary radiation contributions and air plus ground scattering. We also utilized the state-of-the-art 2-D TWODANT transport code[5] as a supplemental tool for generation of radiation dose maps around the casks. We ran these codes on the CRAY machine at San Diego Supercomputer Center.

The analyses considered both normal transport and hypothetical accident conditions to comply with 49CFR173 and 10CFR71. The shielding models for these two conditions

differ only in the assumption that the neutron shield remains intact during normal transport, but completely disappears following a hypothetical fire accident. The results of the analyses show that radiation levels external to the casks are all within the regulatory dose limits for transportation. The general dose rate at the surface of each cask is normally around 50 mrem/h, which allows contact handling of the cask when loaded. The maximum accident dose rate at one meter from the damaged cask after complete loss of the neutron shield is less than 500 mrem/h, which is only 50% of the regulatory dose limit.

In summary, the GA-4 and GA-9 casks incorporated special shielding design features which led to the most efficient configurations with minimum weights and maximum payloads. The non-conventional cask configurations necessitated the use of advanced, sophisticated computer codes for shielding analyses. The cask designs maximize the payloads and meet the regulatory transportation dose limits. The maximum payloads will reduce the number of fuel shipments which in turns, will minimize the life cycle cost and meet the ALARA criteria for radiation exposures.

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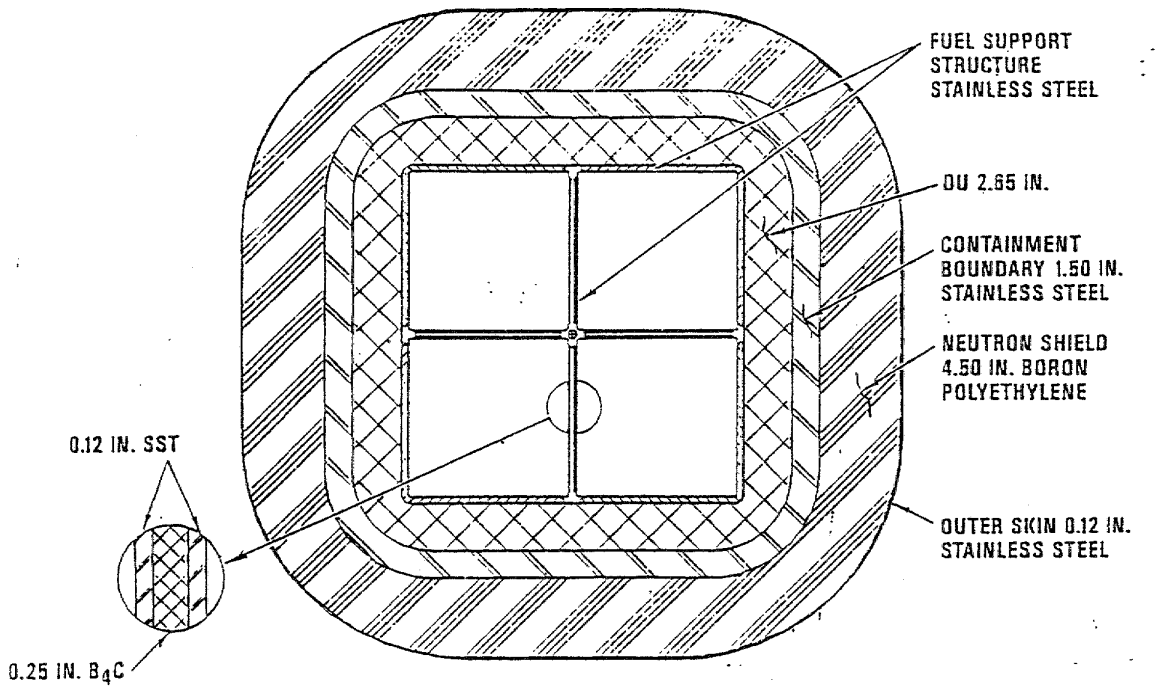
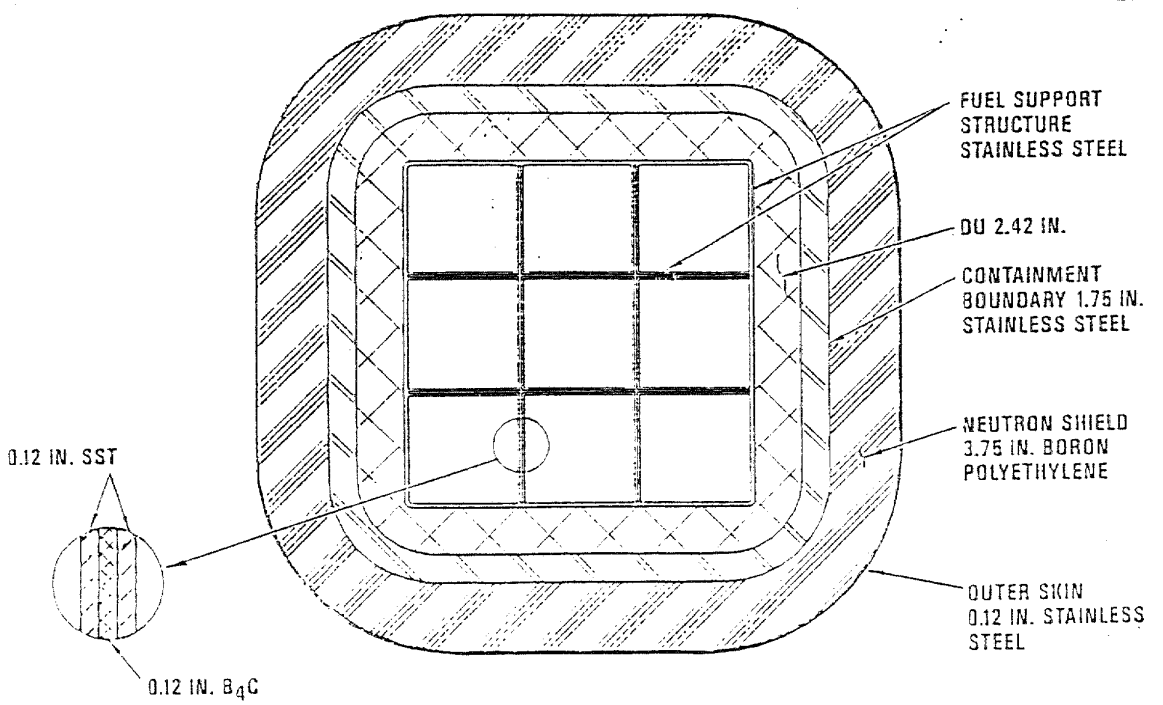


GA-4 CASK: 4 PWR FUEL ASSEMBLY PAYLOAD



GA-9 CASK: 9 BWR FUEL ASSEMBLY PAYLOAD

Fig. 1. GA-4 and GA-9 fuel shipping cask configurations