Repository Waste Package Transporter Shielding Weight Optimization

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INTRODUCTION

The Yucca Mountain repository requires the use of a waste package (WP) transporter to transport a WP from a process facility on the surface to the subsurface for underground emplacement. The transporter is a part of the waste emplacement transport system, which includes a primary locomotive at the front end and a secondary locomotive at the rear end. The overall system with a WP on board weighs over 350 metric tons (MT). With the shielding mass constituting approximately one-third of the total system weight, shielding optimization for minimal weight will benefit the overall transport system with reduced axle requirements and improved maneuverability.

With a high contact dose rate on the WP external surface and minimal personnel shielding afforded by the WP, the transporter provides radiation shielding to workers during waste emplacement and retrieval operations. This paper presents the design approach and optimization method used in achieving a shielding configuration with minimal weight.

SHIELDING DESIGN APPROACH

Shielding design for the transporter balances the overall weight constraint and radiological safety requirements. The design achieves an optimized shielding configuration by using the key design features such as appropriate shielding materials, an efficient geometric layout, and an optimum neutron-to-gamma dose ratio.

The design dose rate limit on the transporter surface is also a key factor affecting the shielding mass. The transporter shielding is engineered to reduce the dose rate to a level of 100 mrem/hr or less on the transporter surface to provide a margin within the limit for a "radiation area" as defined in 10 CFR 20.1003 [1].

Because of the physical size of the WP (~1.6 m in diameter and ~5 m long), the transporter requires substantial shielding including both neutron and gamma shielding to meet the design dose rate of 100 mrem/hr [2]. The required massive shielding introduces several design issues such as transporter axle requirements, maneuverability of the transporter, and reliability of the transporter door mechanism. Extensive shielding calculations are performed with the MCNP4B code [3] for weight optimization purposes to mitigate these design issues.

The transporter design utilizes a "one size fits all" approach to accommodate the different waste forms to be received at the repository and packaged into different WP configurations for underground emplacement. The shielding design considers the limiting waste form and WP configuration, which have been determined to be pressurized-water-reactor (PWR) spent fuel in the 21 PWR fuel assemblies WP, respectively [4]. Figure 1 illustrates the WP transporter. The minimum inside dimensions of the WP transporter are ~6 m (length) x ~2.2 m (width) x ~2.4 m (height).

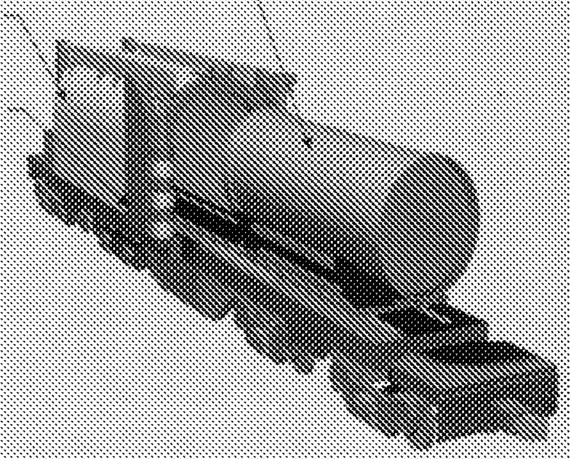

Fig. 1. Illustration of the WP transporter.

Shielding analyses for the WP transporter use the neutron and gamma source terms generated with the SAS2H module of the SCALE code package [5] for the design basis fuel having the characteristics of 4% initial enrichment, 60 GWd/MTU burnup and 10 years cooling from reactor discharge [6]. These specifications translate into a radiation field of 600 rem/hr on the radial surface of the waste package, comprising about 5% from neutrons and 95% from gammas [7].

SHIELDING OPTIMIZATION ANALYSIS

Optimization focused on selection of an effective gamma shielding material, as the gamma shielding mass constitutes the bulk of the overall transporter weight. The gamma shielding candidates selected for the analysis were common engineering materials including A516 carbon steel, lead (Pb), and depleted uranium (DU). Borated polyethylene (B-poly) was used as neutron shielding material in all cases. The gamma shielding material is the inner shell of the WP transporter and the neutron shielding material is the outer shell.

Optimum neutron-to-gamma dose ratio was evaluated for the B-poly neutron shielding material and the various gamma shielding material for the WP transporter. The surface dose rate of the WP transporter was maintained at 100 mrem/hr. It was noticed that the optimized shielding mass is fairly insensitive to neutron-to-gamma dose ratio over the range of 15-35% neutron plus secondary gamma contribution.

The gamma shielding candidates were evaluated from a shielding effectiveness viewpoint. Table I indicates that DU is the most effective gamma shielding material followed by Pb and then A516. The mass calculations are performed in the radial direction of the WP transporter.

TABLE I. Gamma Shielding Material Effectiveness.

Description		A516	Pb	DU
Radial Shielding Thickness				
Gamma Shield	(mm)	152	89	51
	(in.)	6.0	3.5	2.0
B-Poly Shield	(mm)	203	222	210
	(in.)	8.0	8.75	8.25
Shielding Mass (MT/m)				
Gamma Shield		8.8	7.2	6.8
B-Poly Shield		1.6	1.7	1.6
Total Mass		10.4	8.9	8.4

CONCLUSIONS

The WP transporter shielding mass results indicate that DU is most effective for gamma shielding followed by PB and A516 carbon steel. Consequently, use of depleted uranium results in the lowest shielding mass.

The weight optimization represents only one aspect of the shielding material selection for the WP transporter. Final shielding material and configuration selection needs to include other considerations such as material cost, ease of fabrication, structural strength and licensing requirements.

REFERENCES

1. 10 CFR 20.1003. 1999. Energy: Standards for Protection Against Radiation, Definitions.
2. BSC (Bechtel SAIC Company) 2004. *Project Design Criteria Document.* 000-3DR-MGR0-00100-000-003. Las Vegas, Nevada: Bechtel SAIC Company.
3. J. F. BRIESMEISTER, Ed., *MCNP-A General Monte Carlo N-Particle Transport Code*, LA-12625-M, Version 4b, Los Alamos, New Mexico: Los Alamos National Laboratory (1997).
4. BSC (Bechtel SAIC Company), *Waste Package Transporter Shielding Design Calculation*, 000-00C-HE00-00100-000-00A, Las Vegas, Nevada (2004).
5. CRWMS M&O (Civilian Radioactive Waste Management System Management & Operating Contractor), *User Manual for SCALE-4.4A*, 10129-UM-4.4A-00, Las Vegas, Nevada (2000).
6. BSC (Bechtel SAIC Company). *Subsurface Shielding Source Term Specification Calculation.* 000-00C-WER0-00100-000-00A. Las Vegas, Nevada (2002).
7. BSC (Bechtel SAIC Company), *Dose Rate Calculation for 21-PWR Waste Package*, 000-00C-DSU0-01800-000-00B, Las Vegas, Nevada (2004).