Conf-9506150--6

UCRL-JC-120849
PREPRINT

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U.S. Department of Energy
Defense Programs
2nd Annual Packaging Workshop

San Francisco, CA
June 12-15, 1995

April 28, 1995

Lawrence Livermore National Laboratory

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A COMPARISON OF THE SHIELDING PERFORMANCES OF THE AT-400A, MODEL FL AND MODEL AL-R8 CONTAINERS*

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Abstract

A comparison of the neutron and photon dose rates at different locations on the outside surface of the Model AL-R8, Model FL and the AT-400A containers for a given pit load has been done in order to understand the shielding characteristics of these containers. The Model AL-R8 is not certified for transport and is only used for storage of pits, while the Model FL is a certified Type B pit transportation container. The AT-400A is being developed as a type B pit storage and transportation container. The The W48, W56 and B83 pits were chosen for this study because of their encompassing features with regard to other pits presently being stored. A detailed description of the geometry and materials of these containers and of the neutron and photon emission spectra from the actinide materials present in the pit have been used in the calculations of the total dose rates. The calculations have been done using the three-dimensional, neutron-photon Monte Carlo code MCNP. The results indicate the need for a containment vessel (CV), as is found in the Model FL and AT-400A containers, in order to assure compliance with 10 CFR 71 regulations. The absence of a CV in the AL-R8 container results in total dose rates well above of the 200mr/hr allowed by the regulations for the W56 pit. Similar behavior will be expected for other pits with configuration similar to the W56 in which the main contribution to the dose rate is from the fission photons.

* This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

Introduction

Present Department of Energy (DOE)[1] policies call for the disassembly of a large number of weapon systems. These weapons will be transported to disassembly plants and subsequent to disassembly operations required for the storage of the actinide and activated components. These efforts require the availability of appropriate shipping containers (usually Type B packages) which comply with the Code of Federal Regulations (CFR), Title 10, Part 71 (10 CFR 71)[2] and Title 49, Parts 170 to 189 (49 CFR 170-189)[3] and other Code sections. Furthermore, DOE requires that a safety analysis report for packaging (SARP) be prepared before the shipment of any special radioactive Type B assembly, showing compliance with the regulations.

Presently, the Model FL is the only existing container that is certified to transport weapon pits. More recently, DOE has commissioned Sandia National Laboratory (SNL), Lawrence Livermore National Laboratory (LLNL), and Los Alamos National Laboratory (LANL) to design and build the AT-400A container which is expected to be used to both transport and store pits. The AT-400A, is presently undergoing tests to show compliance with the regulations and its SARP is expected to be presented to DOE for approval early next year.

A comparison of the shielding characteristic of the Model AI-R8, the Model FL and the AT-400A containers is of interest because they are being used and because of differences in the materials and dimensions among these containers. For this comparison, we have taken three pits: the W48, W56 and B83, which because of their radiation spectra encompass many, of the US pit types. This comparison allows us to learn about the differences in shielding performance of these containers regarding the absorption of the neutron and photon fission spectra from the enclosed pit.

The calculations of the neutron and photon spectra have been done with the ORIGEN code from the SCALE-4 package[4]. All the isotopes of uranium(232 to 238 and plutonium (236 to 242) have been included in the source calculations. The calculation of the dose rates has been performed using the three-dimensional, neutron-photon. Monte Carlo code[5], MCNP.

Model AL-R8 Container

This container [6], developed by DOW Chemical in the late 1960's, is now used only to store pits. In 1974 the AL-R8 container obtained a certification as a Type B packaging from DOE/AL, allowing it to be used to move pits between production and assembly sites, mainly between Rocky Flats and Pantex Plants. A revised SARP was issued in 1988, however it was found that this container did not comply with all Federal Transport Regulations in 10 CFR 71 and in 1991 the Transportation Safety Review Panel (TSRP) recommended[7] that this container not be used as a Type B packaging. However, it is still used to store different weapon components, including pits.

The main components of the AL-R8 container are: a) a confinement drum, b) a rigid fiberboard and refractory insulation, and c) a pit support frame. The AL-R8 does not have a containment vessel (CV) because it assumes that the pit itself provides sufficient containment

a) The confinement drum is a light weight carbon steel drum with a minimum I.D. of 46 cm (18.12") and 0.122 cm (0.048") nominal thickness. It comes in four different heights: 76, 102, 127 and 152 cm (30", 40", 50" and 60") to accommodate different size loads. See Fig. 1.

b) The fiberboard (Celotex trademark) with a minimum density of 0.240 gr/cm,^{3} provides thermal insulation, shock protection and centers the pit inside the drum. It has been laminated into panels from which disks and rings are cut to the appropriate size to completely enclose the pit positioned in the clamping frame. The minimum thickness of the fiberboard along the side of the drum is 7.00 cm (3" nominal thickness) and 5.00 cm at the top and bottom (2" nominal thickness).

A square sheet of porous refractory fiber insulation (darker zone below the lid of the container in Fig. 1), 30.5x30.5 cm^2 (12"x12") and 1.27cm thick (0.5") is positioned between a 2.54 cm diameter vent hole on the drum lid and the top fiberboard in order to minimize the thermal degradation of the latter. The density of this refractory material is ρ = 0.128 gr/cm.^{3}

c) The pit holding feature consist of a clamping ring around the pit and a light frame (0.42 cm thick) both made of steel. They position the pit in the center of the cavity formed by the fiberboard rings between the bottom and top disks. The frame is held by cutouts in the side fiberboard wall. In the case of large and heavier pits, as in the B83 case, the sides of the cavity are lined with a 0.122 cm thick sheet metal to avoid the frame damaging the fiberboard walls under accident conditions.

The holding feature was not included In the calculations of the dose rates for the W48, W56 and B83 pits. Their inclusion would result only in a minor perturbation of the final values. For the calculation of the B83 dose rates, the sheet metal liner was included.

Model FL Container

The main components of the Model FL container[7] are: a) a 304 stainless steel (SSTL) confinement drum, b) a rigid fiberboard (Celotex) insulation, as in the AL-R8 Model, c) a bolted inner 304 SSTL containment vessel. and d) a pit holder frame. See Fig. 2.

a) The 304 SSTL outside drum has a 56.52 cm ID (22.25"), 123.4 cm (48.6") height and 0.152 cm (0.060") thickness. The density is 8.03 gr/cm.^{3}

b) The Celotex insulation has a nominal thickness of 10 cm (nominal 4") at the bottom and sides of the container and 11.43 cm (4.5") at the top.

c) The inner containment vessel made of 304 SSTL, has a 35 cm (13.8") ID, 96.5 cm (38") height and thicknesses of 0.635 cm (0.250"), 0.266 cm (0.105") and 1.270 cm (0.500") at the bottom side and top walls respectively.

d) The pit supporting frame, similar to the one used in the AL-R8 container, was not included in the dose rate calculations.

The AT-400A Container

The AT-400A has been designed[8] for the storage and transportation of Pits. The main components of this container of interest for its shielding characte-ristics are: an overpack and a containment vessel (CV). The overpack consists of two concentric 304 SSTL shells, the outside container and an inside liner, separated by a thick layer of polyurethane foam. In addition, there is the pit support structure inside the CV.

a) The outside container is a SSTL can (ρ=8.028 gr/cm^3) with a nominal thickness of 0.122 cm (0.048"), a maximum ID of 50.16 cm (19.75"), and 68.45 cm (26.95") height.

b) The polyurethane foam is placed between the side walls of the outside container and the liner. It has a density, ρ = 0.482 gr/cm,^{3} and a nominal thickness of 6.98 cm (2.75"). There are also foam inserts at the bottom and top in the container. The foam in these inserts has been packed inside a thin SSTL, 0.190 cm (0.075") case, conforming with the shape of the top and bottom external surfaces of the containment vessel (see Fig. 3). The maximum thickness of the foam at the edges of the insert is 14.07 cm (5.54"), decreasing gradually to 6.65 cm (2.58") at the center, along a concave elliptical surface that fits the CV top and bottom surfaces.

c) The liner, running from top to bottom along the vertical surface of the foam, is a SSTL sheet, 0.190 cm (0.075") thick with a 36.19 cm (14.25") ID.

d) The containment vessel (CV) is a two piece SSTL container, with a welded closure. It is a cylinder 0.635 cm thick (0.250"), with a 34.29 cm ID (13.5") and 30.23 cm height (11.9") with ellipsoidal shaped caps at both ends that extend its total length along its axis to 48.10 cm (18.92"). At the top cap, the SSTL thickness is 2.14 cm (0.844").

e) The pit support frame is made of two 1.87 cm (0.735") thick circular aluminum plates with the appropriate size center openings to fit each pit. The pit is positioned between these two plates and four SSTL rods, 1.90 cm (0.750) outside diameter, symmetrically positioned around the edge of the plates, to assure a constant spacing between the two Al plates. This frame is mounted on an Al transition flange 0.317 cm (0.125")) thick, which is fastened to the inside wall of the containment vessel where the wall thickens to form a ledge, 3.17cm (1.25") wide at the intersection of the cylindrical and bottom ellipsoidal surfaces of the CV (see Fig. 3). This flange provides shock mitigation for the pit support frame.

Neither the pit support frame, nor the transition flange were included in the comparison study presented in this work, to be consistent with the dose rates calculations presented for the AL-R8 and Model FI containers. However, calculations done with the frame showed differences no larger than the quoted statistical errors for the values obtained without the frame, as is the case for the two other containers.

Table I summarizes the main components of these three containers.

Dose Rate Calculations

A detailed three-dimensional geometrical model of the containers and isotopic composition of the different materials were used in the calculational model of the dose rates. The neutron and photon sources in the Pits were calculated with the ORIGEN-S[4] code which does an accurate calculation of the fission neutron and photon spectra from radioactive materials by including fuel depletion, actinide transmutation, and fission product buildup. The neutron spectrum includes both the contribution of the fission neutrons and that from the (α,n) reactions[9] in the metals present in the pit.

The dose rate calculations were done with the MCNP code[5]. The neutron and photon fluxes are calculated independently with the MCNP code. However, in the calculation of the neutron flux the code allows a coupled neutron-photon calculation, which in addition to giving the neutron flux, also gives the photon flux produced from neutron inelastic reactions [(n,γ), (n,n'γ)].

The neutron and photon fluxes in units of neutrons/cm^2/s and gammas/cm^2/s were converted to dose rates (rem/hour or mrem/hour) using the conversion factors given[10] by the American National Standard Institute (ANSI/ANS6.1.1}. These conversion factors were entered in the input file of the MCNP calculation to get the output directly in dose rate units.

In Tables II, III and IV are tabulated the dose rates for the W48, W56 and B83 pits respectively. The values were calculated at the surface of the outside drum for three locations: at the center of the bottom and top of the drum, and around the side wall at a height coinciding with the center plane of the pit inside the container. A comparison of the dose rates for AL-R8, Model FL and AT-400A containers is given in each of these tables

Discussion and Conclusions

The dose rates calculated outside the AL-R8 container are systematically higher for all three pits, in particular, their photon dose rates. This is an expected result for this container given the absence of an interior containment vessel. In the case of the W56 and other pits with similar structure, the dose rates are larger than the 200 mrem/hour allowed by the 10 CFR 71.47 regulations under normal conditions of transport. These results verify that the AL-R8 container cannot be certified as a type B packaging.

The comparison of the dose rates calculated for the Model FL and AT-400A containers showed that the values calculated at the top and bottom surfaces of the Model Fl container are lower than those obtained at the same locations for the AT-400A container. These lower values are only the result of the difference in height of these two containers; the Model FL container with 123 cm versus the AT-400A with 68 cm height. A calculation of the dose rates for the Model-FL, assuming the same height as the AT-400A container, raised the neutron and photon dose rates at the bottom and top locations by approximately a factor of 2.7. For the W48, the new values for the total dose rates are 11.0 and

8.7 compared to 3.6 and 3.8 mrem/hour in Table II. For the W56, they are 21.2 and 11.9 compared to the 7.2 and 7.5 mrem/hour given in Table III, and for the B83 they are 4.8 and 4.2 compared to 1.5 and 1.7 mrem/hour given in Table IV.

Furthermore, the values of the photon dose rates at the side wall of the Model FL are larger by more than a factor of 2 than those calculated for the AT-400A, even though the Model-FL container has a slightly larger ID (56.5 cm) than the AT-400A (50.2 cm). The thicker SSTL wall of the containment vessel in the AT-400A, 0.635 cm compared to 0.266 cm in the Model FL accounts for the above difference.

The values of the neutron dose rates are essentially the same for the three containers. This is expected since none of the containers includes special neutron shielding materials (i.e. borate paraffin or lithium compounds) in their design because of the small contribution of the neutrons to the total dose rates.

The present work shows that the design of the AT-400A container results in the lowest values of the total dose rates at the surface of the outside container for the pits chosen for this comparison: W48, W56 and B83. Given the characteristics of these pits, one may conclude that these results can be extended to any other US pit type.

Acknowledgements. The author would like to thank G. L. Dittman for a critical reading of the manuscript.

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Tables

Table I. Main packaging components in the AL-R8, Model FL and AT-400A containers. The density of the materials are given in gr/cm^3 and their side wall thicknesses (t), inside diameter (ID) and height (h) in cm. See text for details of the bottom and top container thicknesses.

	MODEL AL-R8	MODEL FL	AT-400A
Outside Container	Carbon-STL ρ=7.89, t=.122 ID=46.0, h=76.2	304-SSTL ρ=8.03, t=.152 ID=56.5, h=123.4	304-SSTL, ρ=8.03, t=.132 ID=50.2, h=68.5
Insulation	Fiberboard (Celotex) ρ=0.240, t=5.88 ID=34.3	Fiberboard (Celotex) ρ=0.240, t=10.0 ID=42.5	Polyurethene Foam ρ=0.482. t=6.83 ID=36.5
Liner	--------------	--------------	SSTL, ρ=8.03, t=.190 ID=36.1
Inside Container	--------------	304-SSTL ρ=8.03, t=.266 ID=36.0, h=96.5	304-SSTL ρ=8.03, t=.635 ID=34.3, h=48.1
Pit Holder Frame	√	√	√

Table II. Values of the dose rates* at the surfaces of the AL-R8, Model FL and At-400A containers with a W48 Pit. The statiscal errors are less than 3%.

	AL-R8				Model FL				AT-400A		
	Botm.	Top	Side		Botm.	Top	Side		Botm.	Top	Side
Total	9.3	22.0	73.2		3.6	3.8	19.8		7.5	7.2	15.1

Table III. Values of the dose rates* at the surfaces of the AL-R8, Model FL and At-400A containers with a W56 Pit. The statiscal errors are less than 5%.

	AL-R8				Model FL				AT-400A		
	Botm.	Top	Side		Botm.	Top	Side		Botm.	Top	Side
Total	86.7	192.	216.		7.2	7.5	51.1		14.6	9.6	22.6

Table IV. Values of the dose rates* at the surfaces of the AL-R8, Model -FL and At-400A containers with a B83 Pit. The statiscal errors are less than 5%.

	AL-R8				Model FL				AT-400A		
	Botm.	Top	Side		Botm.	Top	Side		Botm.	Top	Side
Total	7.3	19.3	13.0		1.5	1.7	12.5		4.3	3.1	8.7

* All values are given in mrem/hour

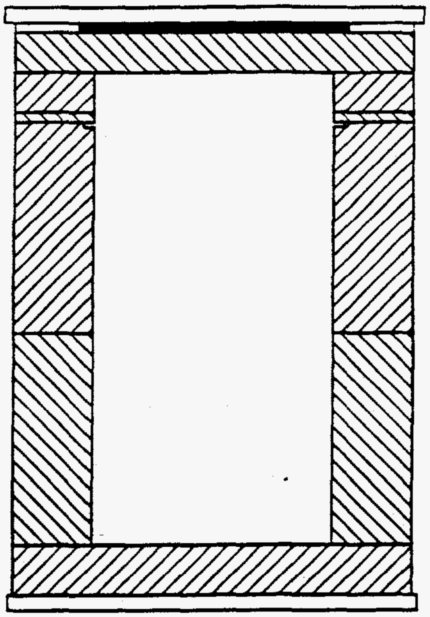

Fig. 1. Model AL-R8 Container

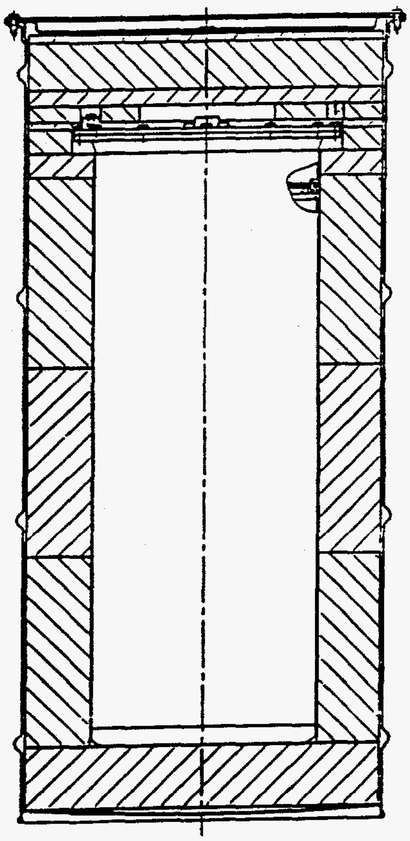

Fig. 2. Model FL Container

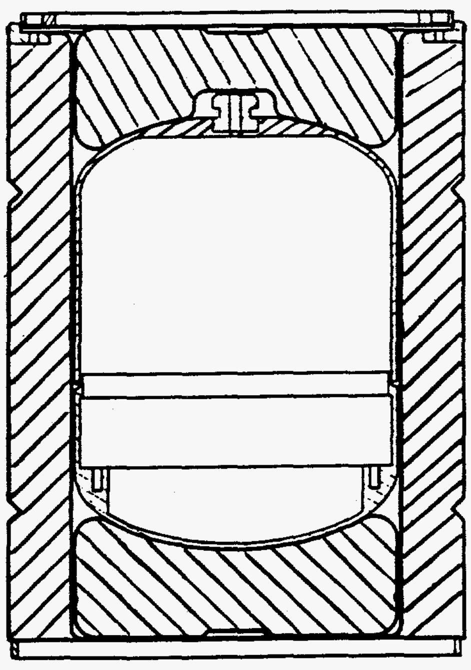

Fig. 3. AT-400A Container

For details on these containers, see Text.