MAY 10 1996 (21) Sta. 21

ENGINEERING DATA TRANSMITTAL

1. EDT 603245

2. To: (Receiving Organization) Packaging Safety Engineering	3. From: (Originating Organization) Nuclear Physics and Shielding	4. Related EDT No.: 603245
5. Proj./Prog./Dept./Div.: Transportation and Packaging	6. Cog. Engr.: J. V. Nelson	7. Purchase Order No.: NA
8. Originator Remarks: For clearance and release		9. Equip./Component No.: NA
		10. System/Bldg./Facility:
11. Receiver Remarks:		12. Major Assm. Dwg. No.: NA
		13. Permit/Permit Application No.: NA
		14. Required Response Date:

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Desig-nator	(G) Reason for Trans-mittal	(H) Origi-nator Dispo-sition	(I) Receiv-er Dispo-sition
1	WHC-SD-TP-ANAL-007		0	Shielding Analysis of the Long Length Contaminated Equipment Transportation Package	NA KN			

16. KEY

Approval Designator (F)	Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)	1. Approval 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment	4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)

(G) Rea-son	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Rea-son	(H) Disp.
1		Cog.Eng. J. V. Nelson	J V Nelson	5-7-96	H0-35						
1		Cog. Mgr. J. Greenborg	J. Greenborg	5/7/96	H0-35						
		QA									
		Safety									
		Env.									
4	/	R. L. Simons	R L Simons	5-7-96	H0-35						
4	/	D. E. Lessor	D. E. Lessor	5-7-96	H0-35						

18.	19.	20.	21. DOE APPROVAL (if required)
J. V. Nelson J V Nelson 5-7-96 Signature of EDT Originator / Date	Authorized Representative for Receiving Organization / Date	J. Greenborg J. Greenborg 5/7/96 Cognizant Manager / Date	Ctrl. No. [] Approved [] Approved w/comments [] Disapproved w/comments

BD-7400-172-2 (04/94) GEF097

BD-7400-172-1 (07/91

Shielding Analysis of the Long Length Contaminated Equipment Transportation Package

Joseph V. Nelson
Westinghouse Hanford Company, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-87RL10930

EDT/ECN: 603245 UC: 513
Org Code: 8M730 Charge Code: N1782
B&R Code: EW3130010 Total Pages: 19 KN

Key Words: Long length equipment, transportation package, shielding analysis, nuclear waste

Abstract: A shielding analysis of a potential long length contaminated equipment transportation package was completed. The analysis was performed to support the design of the transportation package and external shielding.

MAY 10 1996
DATE: HANFORD
STA: 21 RELEASE ID: 21

Karen M. Noland 5/10/96
Release Approval Date

Release Stamp

Approved for Public Release

SHIELDING ANALYSIS OF THE LONG LENGTH CONTAMINATED EQUIPMENT TRANSPORTATION PACKAGE

1.0 INTRODUCTION

This report presents the results of a preliminary analysis of dose rates around a potential long length contaminated equipment (LLCE) transportation package. The analysis was completed to support the design of this transportation package and external shielding.

The transportation package consists of a long polyethylene container, 21.3 m (70 ft) in length. Inside this pipe is a steel half-shell pipe used as a skid for the LLCE. A variety of LLCE must be accommodated by the packaging. The length of this equipment ranges from 3.6 m (12 ft) to 18.9 m (62 ft). The source term used in the shielding analysis of the proposed LLCE shipments was based on a worst-case evaluation.

2.0 DIRECT RADIATION SOURCE SPECIFICATION

The worst-case source term used in this analysis was the one used previously in the safety class analysis of LLCE packaging (Ref. 1). This source is listed in Table 1.

2.1 Gamma Source

The source term listed in Table 1 was used as input to the ISOSHLD program (Ref. 2) to compute a photon source rate as a function of photon energy. The resulting energy distribution is listed in Table 2. The total source rate was computed by ISOSHLD to be 4.68×10^{13} photons/sec.

2.2 Beta Source

The beta source within the loaded LLCE container leads to an insignificant dose rate outside the perimeter of the trailer because of the shielding provided by steel in the LLCE, the steel skid plate, the grout filler, the polyethylene container, the trailer deck and external shielding. This shielding is described in Section 4.0.

2.3 Neutron Source

Actinides listed in Table 1 are in very low concentrations. Thus, neutron dose rates were expected to be negligible compared to photon dose rates. This was confirmed using the method described in Reference 3 to conservatively estimate neutron doses at several locations around the trailer. Since the neutron dose rates are insignificant, they are not reported.

Table 1. Radionuclide Inventory in the LLCE

Isotope	Activity*	
	Bq	Ci
^{14}C	2.25E+09	6.07E-02
^{60}Co	1.23E+12	3.32E+01
^{63}Ni	3.63E+10	9.81E-01
^{79}Se	9.03E+07	2.44E-03
^{90}Sr	7.70E+12	2.08E+02
^{90}Y	7.70E+12	2.08E+02
^{93m}Nb	2.22E+08	6.01E-03
^{93}Zr	3.24E+08	8.77E-03
^{95}Zr	2.80E+11	7.57E+00
^{99}Tc	5.14E+10	1.39E+00
^{106}Rh	3.22E+11	8.70E+00
^{106}Ru	3.22E+11	8.70E+00
^{125}Sb	1.95E+11	5.27E+00
^{129}I	3.15E+07	8.52E-04
^{134}Cs	5.14E+10	1.39E+00
^{137}Cs	3.37E+13	9.10E+02
^{137m}Ba	3.19E+13	8.61E+02
^{144}Ce	1.57E+13	4.24E+02
^{144}Pr	1.57E+13	4.24E+02
^{147}Pm	5.85E+09	1.58E-01
^{151}Sm	6.22E+10	1.68E+00
$^{154/155}Eu$	4.18E+10	1.13E+00
^{233}U	9.29E+06	2.51E-04
^{234}U	8.58E+03	2.32E-07
^{235}U	2.58E+06	6.98E-05
^{237}Np	1.10E+07	2.96E-04
^{238}Np	7.07E+04	1.91E-06
^{238}Pu	2.86E+08	7.72E-03
^{238}U	6.25E+07	1.69E-03
^{239}Pu	1.48E+10	4.00E-01
^{240}Pu	6.88E+08	1.86E-02
^{241}Am	1.36E+10	3.67E-01
^{241}Pu	6.62E+09	1.79E-01
^{242}Am	1.41E+07	3.81E-04
^{242}Cm	4.26E+07	1.15E-03
^{242m}Am	1.42E+07	3.83E-04
^{242}Pu	4.48E+01	1.21E-09
^{243}Am	4.03E+08	1.09E-02
^{244}Cm	5.85E+07	1.58E-03

* The format of the activities is z.dE±ee, which is interpreted as z.d x $10^{\pm ee}$.

Table 2. Photon Source Rate Energy Distribution

Average Energy (MeV)	Photon Source Rate* (photons/sec)
0.015	2.496E+12
0.025	1.372E+12
0.035	4.253E+12
0.045	8.709E+11
0.055	4.149E+11
0.065	3.177E+11
0.075	2.618E+11
0.085	4.993E+11
0.095	2.149E+11
0.150	3.002E+12
0.250	3.994E+11
0.350	2.002E+11
0.475	2.977E+11
0.650	2.928E+13
0.825	2.412E+11
1.000	3.261E+10
1.225	2.476E+12
1.475	5.809E+10
1.700	2.796E+09
1.900	1.189E+09
2.100	1.213E+11
2.300	1.935E+08
2.500	5.875E+07
2.700	1.282E+07
3.000	2.542E+06
3.600	1.198E+05
Total	4.681E+13

* The format of the source rate data is z.dE±ee, which is interpreted as $z.d \times 10^{\pm ee}$.

3.0 CALCULATIONAL METHOD

All dose rate calculations were made using the Hanford version (Ref. 4) of the Monte Carlo code MCNP (Ref. 5). For expediency, initial scoping calculations were made using the point-kernel option in the code. However, any contribution to a dose rate from ground shine cannot be quantified using the point-kernel method. Because of the minimal amount of shielding on the bottom of the transportation package, final MCNP calculations were made using the rigorous transport mode to account for ground shine. Unless noted otherwise, results presented in Sections 5.0 and 6.0 are from the transport calculations. Dose rates were tallied in MCNP using the point detector option.

In all cases, photon cross section data from the ENDF/B-V library were used, and photon fluxes were converted to dose rates using ANSI/ANS-6.1.1-1991 fluence-to-dose conversion factors.

Results from Monte Carlo calculations are subject to statistical uncertainties. MCNP provides an estimate of the uncertainty for each computed dose rate. However, there is a statistical uncertainty on this estimate. When using point detectors to tally dose rates, MCNP uncertainties estimated to be less than 5% are generally reliable. Uncertainty estimates in the 5% to 10% range tend to be reasonably reliable, but should be treated with caution.

For uncertainties larger than 10%, there can be a large uncertainty in the given uncertainty, and results should be treated as, at most, order of magnitude estimates.

4.0 CALCULATIONAL MODELS

The LLCE container was represented as a long polyethylene pipe lying on a steel flat-bed trailer. A plan view of the calculational model is shown in Figure 1, and a cross section of the model is shown in Figure 2.

The pipe was modeled as having a length of 21.3 m (70.0 ft), an outer diameter (OD) of 170.2 cm (67.0 in.) and a wall thickness of 3.18 cm (1.25 in.). A polyethylene end cap 4.93 cm (1.94 in.) thick was included at each end of the pipe. Inside the polyethylene container is a steel half-shell pipe used as a skid for the LLCE. The skid has an OD of 149.5 cm (58.9 in.) and a thickness of 0.48 cm (0.19 in.). It runs the length of the polyethylene container, and includes steel end plates 0.48 cm (0.19 in.) thick.

The LLCE, which sits on the bottom of the skid, was represented as a column of steel pipe having a length of 18.9 m (62.0 ft), an OD of 108.0 cm (42.5 in.) and a wall thickness of 0.64 cm (0.25 in.). The pipe was modeled as containing 9.1 m (30.0 ft) of uniformly distributed tank waste at one end, with the remaining 9.8 m (32.0 ft) voided. The end with the radioactive source material was located at the front of the trailer. The space around the LLCE inside the polyethylene container was filled with low density (0.32 g/cc) grout, which is intended to provide stability and shielding.

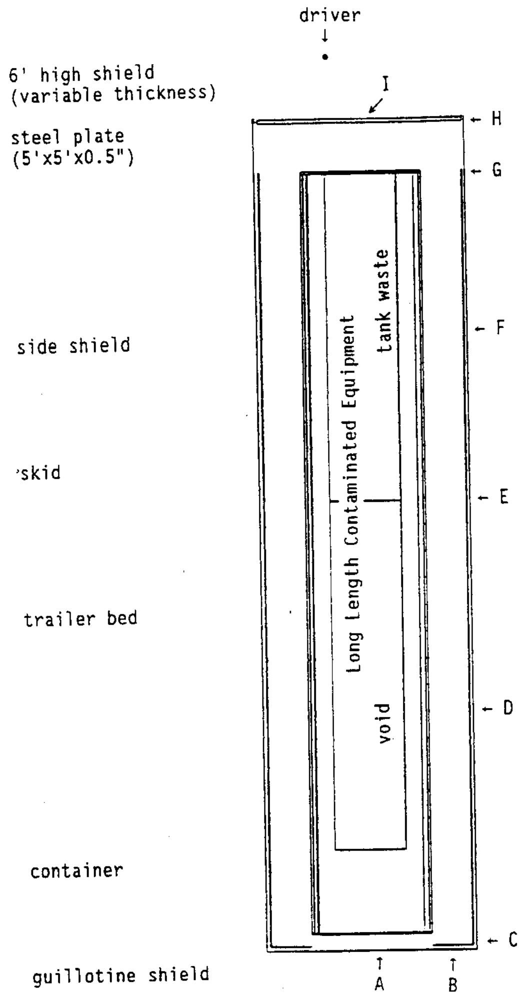
The steel trailer bed was modeled as being 23.2 m (76.0 ft) long, 287 cm (113.0 in.) wide and 0.64 cm (0.25 in.) thick. The top of the trailer bed was set at 228.6 cm (90.0 in.) above ground level. The polyethylene container was positioned 33.9 cm (13.3 in.) from the back of the trailer.

External steel shields on all four sides of the trailer are planned. Along each side of the polyethylene container is a steel plate that runs the length of the container (21.3 m, or 70.0 ft). Each plate, mounted on top of the trailer bed, is 1.27 cm (0.50 in.) thick and 111.8 cm (44.0 in.) tall.

A steel plate was also included in the model directly in front of the polyethylene container. This plate, 152 cm (60.0 in.) square and 1.27 cm (0.50 in.) thick, is intended to stabilize the load and provide needed shielding. Additional shielding to the driver is provided by another steel plate located at the front edge of the trailer. This shield is 182.9 cm (72.0 in.) tall and extends the width of the trailer. The shield thickness was varied from 2.54 cm (1.0 in.) to 12.7 cm (5.0 in.) to determine the effect of shield thickness on the dose rate at the truck driver's location, assumed to be 152 cm (60 in.) in front of the trailer.

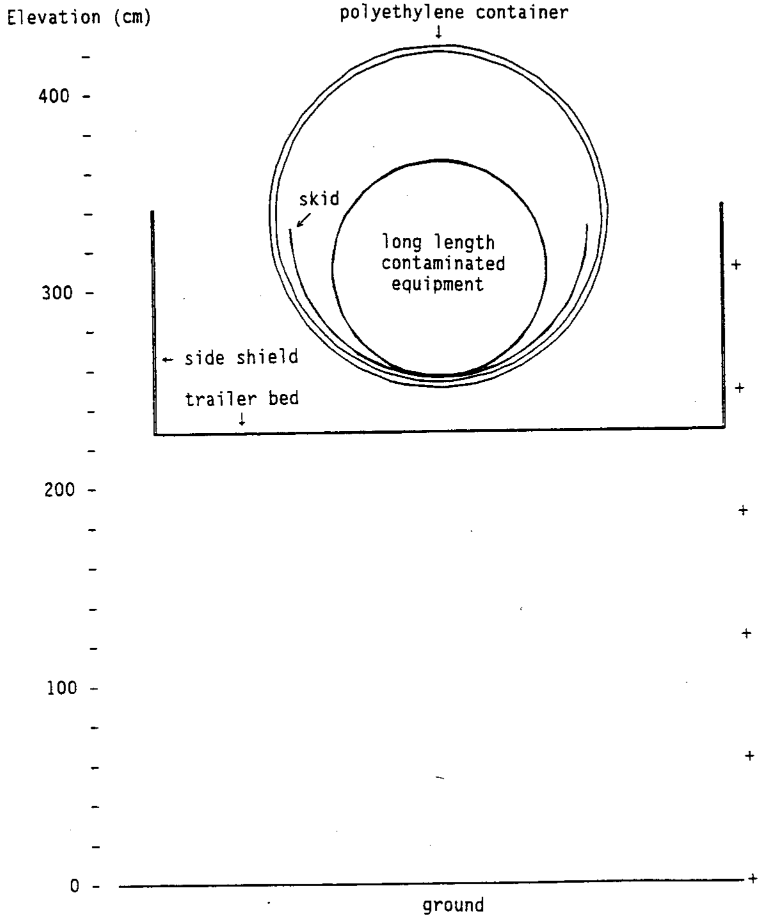
A 2.54 cm (1.0 in.) thick guillotine shield is located at the rear of the trailer to protect workers while the back cover is placed on the polyethylene pipe, and the container void is filled with low density grout. This shield is 213.4 cm (84.0 in.) tall, and runs the width of the trailer. To provide access to the container, there is an opening in the top-center portion of the shield. This opening is 170.2 cm (67.0 in.) wide and begins 21.7 cm (8.5 in.) above the trailer deck.

The ground was modeled as a concrete surface. All air spaces were modeled as voided regions. Thus, while ground shine was accounted for in the model, the effect of photon scattering in air (sky shine) was not. Compositions for all materials used in the calculational model are given in Table 3.



Letters A - I indicate locations where dose rates were computed.
Dose rates were also computed at the driver location.

Figure 1. Plan View of MCNP Calculational Model



+ = elevations at which dose rates were tallied

Figure 2. Cross Section of MCNP Calculational Model

Table 3. Material Compositions

Material (density)	Element	Weight Fraction
Steel (7.8 g/cc)	Fe	1.000
Polyethylene (0.95 g/cc)	H	0.143
	C	0.857
Tank Waste (1.6 g/cc)	H	0.043
	C	0.020
	N	0.079
	O	0.584
	Na	0.220
	Al	0.030
	P	0.003
	Cl	0.010
	K	0.010
Low-Density Grout (0.32 g/cc) & Concrete (2.28 g/cc)	O	0.441
	Si	0.216
	Ca	0.131
	Fe	0.079
	Al	0.061
	Mg	0.038
	K	0.007
	Na	0.018
	Ti	0.005
	H	0.003
	Mn	0.001
	P	0.001
	S	0.001

5.0 RESULTS

Dose rates were computed for points at the front, back and side of the trailer, including the approximate driver location. The locations where dose rates were computed are indicated in Figure 1. Points A and B are behind the trailer. Point A is at the back-center of the trailer where the opening in the guillotine shield is, while point B is behind the tall section of this shield. Points C through H are along the side of the trailer, and point I is at the front-center of the trailer. For all points A through I, dose rates were computed at 0, 1 and 2 meters from the edge of the trailer, and at 6 different elevations ranging from ground level to 305 cm (120 in.) above the ground.

Dose rates at some elevations in front of the trailer (point I and the driver location) depend on the thickness of the front steel shield. MCNP calculations were made using three thicknesses, 2.5, 7.6 and 12.7 cm (1, 3 and 5 in.). Results of the dose rate calculations at points A through I are shown in Table 4.

The location of the driver was assumed to be 152 cm (60 in.) in front of the trailer, and offset 91 cm (36 in.) from the trailer centerline. Two elevations were chosen as representative of the driver's height above the ground while in the cab of the truck. These elevations are 183 cm (72 in.)

and 244 cm (96 in.) above ground level. The computed dose rates at the driver's location as a function of shield thickness are given in Table 5. Any shielding provided by the truck cab and some other components, such as axles, wheels and frames, were not accounted for in the calculational model.

Table 4. Dose Rates around the Transport Trailer (Sheet 1)

Point[a]	Elevation (cm)	Dose Rate (mrem/hr)[b] Contact	1 meter	2 meter
A	0	3.1E+00	2.4E+00	1.9E+00
	61	4.0E+00*	3.4E+00*	2.4E+00*
	122	3.4E+00*	2.8E+00*	2.2E+00
	183	3.0E+00	2.4E+00	2.0E+00
	244	2.1E-01*	1.6E+00	2.0E+00
	305	2.5E-01*	4.9E-01*	3.4E-01*
B	0	3.1E+00	2.4E+00	1.9E+00
	61	3.6E+00*	2.9E+00*	2.3E+00
	122	3.5E+00*	2.8E+00*	2.2E+00
	183	3.9E+00*	2.5E+00	2.0E+00
	244	6.3E-01*	1.7E+00	2.0E+00
	305	2.3E-01*	4.1E-01*	5.3E-01
C	0	3.1E+00	3.2E+00	3.3E+00
	61	3.5E+00	3.4E+00	3.5E+00
	122	3.4E+00*	3.2E+00	3.3E+00
	183	3.5E+00*	2.9E+00	3.1E+00
	244	1.1E+00*	2.8E+00	3.2E+00
	305	1.0E+00	2.8E+00	3.9E+00
D	0	2.4E+01	2.4E+01	2.4E+01
	61	2.6E+01	2.6E+01	2.4E+01
	122	2.0E+01	2.0E+01	1.9E+01
	183	1.5E+01	1.4E+01	1.6E+01
	244	3.9E+00	1.2E+01	1.6E+01
	305	3.7E+00	1.2E+01	1.8E+01
E	0	5.5E+02	4.2E+02	3.1E+02
	61	7.0E+02	5.1E+02	3.3E+02
	122	7.8E+02	4.9E+02	3.0E+02
	183	8.2E+02	4.0E+02	3.0E+02
	244	4.7E+02	4.4E+02	3.1E+02
	305	4.9E+02	4.7E+02	3.4E+02
F	0	1.3E+03	7.7E+02	6.7E+02
	61	1.3E+03	9.5E+02	6.1E+02
	122	1.5E+03	9.1E+02	5.5E+02
	183	1.5E+03	7.6E+02	5.5E+02
	244	8.8E+02	8.0E+02[c]	5.6E+02
	305	8.7E+02	8.3E+02	6.0E+02

a See Figure 1 for location of points.
b The format of the dose rate data is z.dE±ee, which is interpreted as z.d x $10^{\pm ee}$.
c Interpolated value - not computed explicitly by MCNP.
* Dose rates with uncertainty estimates greater than 10%. Use values as order-of-magnitude indicators only.

Table 4. Dose Rates around the Transport Trailer (Sheet 2)

Point[a]	Elevation (cm)	Dose Rate (mrem/hr)[b] Contact	1 meter	2 meter
G	0	5.6E+02	4.7E+02	3.2E+02
	61	7.0E+02	5.0E+02	3.4E+02
	122	7.8E+02	4.8E+02	3.0E+02
	183	8.2E+02	4.0E+02	3.0E+02
	244	4.6E+02	4.2E+02	3.0E+02
	305	4.4E+02	4.3E+02	3.2E+02
H	0	2.5E+02	2.2E+02	1.8E+02
	61	2.7E+02	2.4E+02	1.9E+02
	122	2.4E+02	2.1E+02	1.8E+02
	183	1.9E+02	2.2E+02	1.9E+02
	244	4.1E+02	2.6E+02	1.9E+02
	305	4.5E+02	2.6E+02	2.0E+02
I w/2.5 cm th. front shield	0	2.5E+02	1.4E+02	9.0E+01
	61	2.8E+02	1.6E+02	9.9E+01
	122	2.8E+02	1.6E+02	8.3E+01
	183	3.0E+02	1.2E+02	6.9E+01
	244	1.2E+02	1.3E+02	7.4E+01
	305	1.8E+02	1.4E+02	7.8E+01
I w/7.6 cm th. front shield	0	2.6E+02	1.5E+02	9.2E+01
	61	3.0E+02	1.7E+02	9.8E+01
	122	2.9E+02	1.6E+02	6.7E+01
	183	3.2E+02	7.8E+01	3.1E+01
	244	9.4E+00	3.0E+01	2.3E+01
	305	1.5E+01	2.5E+01	2.1E+01
I w/12.7 cm th. front shield	0	2.6E+02	1.6E+02	9.1E+01
	61	3.0E+02	1.6E+02	9.6E+01
	122	2.9E+02	1.6E+02	6.4E+01
	183	3.2E+02	7.6E+01	3.0E+01
	244	3.6E+00	2.7E+01	2.0E+01
	305	3.5E+01	1.6E+01	1.7E+01

a See Figure 1 for location of points.
b The format of the dose rate data is z.dE±ee, which is interpreted as $z.d \times 10^{\pm ee}$.

Table 5. Dose Rates at Driver's Location as a Function of Front Shield Thickness

Elevation above Ground	Dose Rate (mrem/hr)		
	2.5 cm (1")	7.6 cm (3")	12.7 cm (5")
183 cm (72")	77	42	40
244 cm (96")	78	25	22

The MCNP uncertainty estimates associated with most dose rates given in Tables 4 and 5 are less than 10%, indicating they are probably reliable estimates. However, at locations A, B and C in Figure 1, near the rear of the trailer, uncertainty estimates ranged up to 70%. The high uncertainties are due to low dose rates. Because relatively few photons reached these locations in the MCNP simulation, the statistics were poor. Dose rates in Table 4 with uncertainties larger than 10% are flagged. The flagged values should be used as order-of-magnitude estimates only.

MCNP transport calculations indicated that the effect of ground shine is very significant (16 to 18 mrem/hr) at the driver's location. Ground shine was also relatively significant at the rear of the trailer, where dose rates are lowest. There, ground shine contributed 2 - 3 mrem/hr to the dose rate. Neglecting ground shine, dose rates behind the trailer were computed to be less than 1 mrem/hr (based on point-kernel results). At the side of the trailer near the source region, ground shine did not appear to contribute significantly to the dose rate.

6.0 SHIELDING EVALUATION AND CONCLUSIONS

The calculated peak dose rates for the front, sides and back of the trailer are summarized in Table 6. Dose rates along the side are as high as 1,500 mrem/hr. In general, contact dose rates peak near head level (183 cm or 72 in.). This is just below the elevation of the trailer bed and the shields mounted on it (see Figure 2). These shields are only partially effective in reducing dose rates around the trailer because of the minimal bottom shielding and the height of the trailer bed above the ground (228 cm or 90 in.).

With the current design, the shields at the front of the trailer cannot reduce the dose rate at the driver's location to 2 mrem/hr. Additional bottom shielding or front shielding that extends well below the elevation of the trailer bed is needed. If the front shield is extended down to eliminate both the direct exposure from beneath the shield and ground shine, and its steel thickness is increased to 13 cm (5 in.), the driver's dose rate would be reduced to about 1 mrem/hr with the source term used in this analysis. Also, if the side shields were extended down from the trailer bed, the peak contact dose rate at the side of the trailer could be reduced from 1,500 mrem/hr to about 870 mrem/hr, without increasing shield thickness.

Dose rates at the rear of the trailer are very low compared to peak dose rates on the side and front of the trailer, as shown in Table 6. The greater distance from the radiation source and the shielding effect of the low-density grout filler are the main reasons for this.

As mentioned in Section 3.0, photon scattering in air (sky shine) was not accounted for in the results shown in Tables 4, 5 and 6. A separate calculation indicated that the effect of sky shine is relatively small, but not insignificant at some locations. In particular, accounting for sky shine adds up to 2 mrem/hr to the dose rate near the rear of the trailer, and 6 to 7 mrem/hr at the driver's location when there is a 12.7 cm (5 in.) thick shield at the front of the trailer. Thus, final shielding analyses of the LLCE transportation package should consider the effects of sky shine.

Table 6. Summary of Peak Dose Rates at the Front, Sides and Back of the Transportation Package Trailer

Location	Dose Rate (mrem/hr)		
	Contact	1 meter	2 meter
Peak Side (point F)[a]	1500	950	670
Center Line, Back (point A)[a]	4.0	3.4	2.4
Off Center, Back (point B)[a]	3.9	2.9	2.3
Center Line, Front (point I)[a]			
- 2.5 cm shield[b]	300	160	99
- 5.1 cm shield[b]	320	170	98
- 7.6 cm shield[b]	320	160	96

a See Figure 1 for the location of each point.
b Thicknesses of the 183 cm (72 in.) tall front shield.

7.0 REFERENCES

1. Memo, H. J. Goldberg to J. S. Burgess, "Safety Class Analysis of Long Length Equipment Packaging," 8M730-HJG-95-012, April 13, 1995.

2. Rittmann, P. D., *ISO-PC Version 1.98 - User's Guide*, WHC-SD-WM-UM-030, Rev 0, May 1995.

3. Memo, J. V. Nelson to J. R. Green, "Estimation of Neutron Dose Rates from Nuclear Waste Packages," 8M730-JVN-96-007, March 8, 1996.

4. Carter, L. L., *Certification of MCNP Version 4A for WHC Computer Platforms*, WHC-SD-MP-SWD-30001, Rev. 7, ECN 605701, Westinghouse Hanford Company, Richland, Washington, January, 1995.

5. Breismeister, J. F., Editor, *MCNP - A General Monte Carlo N-Particle Transport Code, Version 4a*, Los Alamos National Laboratory report LA-12625, Los Alamos, New Mexico, 1993.

APPENDIX
LISTING OF SAMPLE MCNP INPUT FILE

```
Long Length equipment trailer--70 ft container - transport calc.
c   trlr70e - 1" th front shield - calc dose on 3 sides of trailer
c
   1    1   -7.80     -1    +2    3    -4     5     -6  $trlr deck
   2    2   -0.95     -7     8   16   -17               $poly container
   3    2   -0.95     -7    10  -16                     $back poly endcap
   4    2   -0.95     -7   -11   17                     $front poly endcap
   5    1   -7.80     -9    14  -15   20   -21          $skid sides
   6    1   -7.80     -9   -15   16  -20                $skid back end
   7    1   -7.80     -9   -15  -17   21                $skid front end
   8    5   -0.32     -8    16  -17   #5   #6    #7     $rest of container
                      (26:-42:21)
   9    4   -1.6     -21    24  -25                     $source region
  10    1   -7.80    -21    42   25 -26                 $LLE pipe
  11    1   -7.80    -31     5  -27   1     -4     3    $Gilatine shld
                      (-28:-29:30)
  12    1   -7.80    -36    31  -32   1    -33     3    $Rt. side plate
  13    1   -7.80    -36    31  -32   1     -4    34    $Left side plate
  14    1   -7.80    -36    11  -37   1    -39    38    $5'x5'x.5" front plate
  15    1   -7.80     -6    41  -40   1     -4     3    $Front shld (6' tall)
  16    0             42   -24  -25                     $Inside empty end of pipe
  30    5   -2.28     50 -51  52 -53 44 -43             $top grnd level
  31    5   -2.28     50 -51  52 -53 45 -44             $2nd grnd level
  32    5   -2.28     50 -51  52 -53 46 -45             $3rd grnd level
 998    0             ( #1 #11 #12 #13 #14 #15 )        $ outside cont., above grnd
                      ( 7 : -10 : 11 )
                      (43 : -46 : -50 : 51 : -52 : 53) -999
 999    0    999                                        $outside universe

   1   pz     228.600                        $ top of tlr deck
   2   pz     227.965                        $bottom of trlr deck
   3   py       0.0                          $right side of trlr
   4   py     287.020                        $ left side of trlr
   5   px       0.0                          $ rear of trlr deck
   6   px    2316.480                        $ front of trlr deck
   7   c/x    143.510   335.4324   85.090    $ cont outer surf
   8   c/x    143.510   335.4324   81.9150   $ cont inner surf
   9   pz     330.0413                       $ top of skid
  10   px      33.8836                       $ outside back end 70' cont
  11   px    2167.4836                       $outside front end 70' cont
  12   px      80.010                        $outside back end 52' cont
  13   px    1664.970                        $outside front end 52' cont
  14   c/x    143.510   330.0413   74.2950   $inside skid surf
  15   c/x    143.510   330.0413   74.7713   $outside skid surf
  16   px      38.8112                       $inside back end 70' cont
  17   px    2162.5560                       $inside front end 70' cont
  18   px      84.9376                       $inside back end 52' cont
  19   px    1660.0424                       $inside front end 52' cont
  20   px      39.2875                       $inside back end 70'skid
  21   px    2162.0798                       $inside front end 70' skid
  22   px      85.4139                       $inside back end 52' skid
  23   px    1659.5662                       $inside front end 52' skid
  24   px    1247.8798                       $back of source region
  25   c/x    143.510   309.73     53.34     $source region
  26   c/x    143.510   309.73     53.98     $LLE pipe
  27   pz     441.96                         $Top of gilatine shld
  28   pz     250.34                         $Top of opening in gil. shld
  29   py      58.40                         $Left side of opening in gil.shld
  30   py     228.62                         $Rt. side of opening in gil.shld
  31   px       2.54                         $Front edge of gil. shld
  32   pz     340.36                         $Top of side shlds
  33   py       1.27                         $Inside edge of rt. side shld
  34   py     285.75                         $Inside edge of left side shld
  36   px    2168.75                         $Front of 5'x5'x.5" front plate
  37   pz     381.00                         $Top of 5'x5'x.5" front plate
  38   py      67.31                         $Rt. side of 5'x5'x.5" front plate
  39   py     219.71                         $Left side of 5'x5'x.5" front plate
  40   pz     411.48                         $Top of 6' front shld
  41   px    2313.94                         $Rear of 6' front shld (1" th)
  42   px     272.32                         $Back end of 62' pipe
  43   pz       0.00                         $Ground level
  44   pz      -7.00
  45   pz     -14.00
  46   pz     -21.00
  50   px    -600.00
  51   px    2900.00
  52   py    -600.00
```

```
  53    py       600.00
 999    s        1158.240    143.510    0.0    4000   $ outside universe marker

mode      p
phys:p    10     1     1
c         idum      2
imp:p     2      7r    1   2   4r   4   1   2   1   0.5   1    0
prdmp     2j   1
c         nps      40000
ctme   6000
sdef      wgt=4.681e13       erg=d1
          pos= 1704.8798      143.510     309.73
          axs=     1             0            0
          rad=d2           ext=d3        cel=9
#        si1              sp1
          l                d
c       Average     Source Total
c       E, MeV       photons/sec
c       -------------------------
          0.015        2.496E+12
          0.025        1.372E+12
          0.035        4.253E+12
          0.045        8.709E+11
          0.055        4.149E+11
          0.065        3.177E+11
          0.075        2.618E+11
          0.085        4.993E+11
          0.095        2.149E+11
          0.150        3.002E+12
          0.250        3.994E+11
          0.350        2.002E+11
          0.475        2.977E+11
          0.650        2.928E+13
          0.825        2.412E+11
          1.000        3.261E+10
          1.225        2.476E+12
          1.475        5.809E+10
          1.700        2.796E+09
          1.900        1.189E+09
          2.100        1.213E+11
          2.300        1.935E+08
          2.500        5.875E+07
          2.700        1.282E+07
          3.000        2.542E+06
          3.600        1.198E+05
c         -------------------------
c          Totals:     4.681E+13 photon/sec
c
    si2    0.    53.34
    sp2    -21      1
    si3         456.98
c
c
    m1        26000         1.0    $ Fe
c
    m2          1001.01p    0.666666  $ H     polyethylene  (CH4)n
                6000        0.333334  $ C
c
    m3          8016.01p    0.21   $ O         air
                7014.01p    0.79   $ N
c
    m4      1001.01p     .4372       $H 101 SY Slurry
            6000         .0170       $C
            7014.01p     .0579       $N
            8016.01p     .3725       $O
           11023.01p     .0975       $Na
           13027.01p     .0113       $Al
           15031.01p     .0011       $P
           17000         .0029       $Cl
           19000         .0026       $K
    m5      8016.01p    -.4407       $O      grout weight fraction
           14000        -.2157       $Si
           20000        -.1306       $Ca
           26000        -.0788       $Fe
           13027.01p    -.0607       $Al
           12000        -.0376       $Mg
           19000        -.0066       $K
           11023.01p    -.0182       $Na
           22000.01p    -.0049       $Ti
            1001.01p    -.0031       $H
           25055.01p    -.0013       $Mn
           15031.01p    -.0009       $P
           16032.01p    -.0009       $S
```

```
c
c     ansi/ans-6.1.1-1991
c     fluence-to-dose,photons(mrem/hr/(p/cm**2/s)
 de0     log  .01 .015 .02 .03 .04 .05
              .06 .08 .10 .15 .20 .30
              .40 .50 .60 .80 1.0 1.5
               2.0 3.0 4.0 5.0 6.0 8.0
              10. 12.
 df0     log  2.232e-5 5.652e-5 8.568e-5 1.184e-4 1.314e-4 1.382e-4
             1.440e-4 1.624e-4 1.919e-4 2.797e-4 3.708e-4 5.616e-4
             7.416e-4 9.144e-4 1.076e-3 1.379e-3 1.656e-3 2.246e-3
             2.758e-3 3.672e-3 4.500e-3 5.292e-3 6.012e-3 7.488e-3
             8.892e-3 1.040e-2
c
fc5       cold end dose rate traverse
f5:p    $      X         Y          Z         R0
               0        31          0          1     $ contact DR
               0        31         61          1
               0        31         122         1
               0        31         183         1
               0        31         244         1
               0        31         305         1
            -100        31          0          1     $ 1 meter DR
            -100        31         61          1
            -100        31         122         1
            -100        31         183         1
            -100        31         244         1
            -100        31         305         1
            -200        31          0          1     $ 2 meter DR
            -200        31         61          1
            -200        31         122         1
            -200        31         183         1
            -200        31         244         1
            -200        31         305         1
               0       144          0          1     $ contact DR
               0       144         61          1
               0       144         122         1
               0       144         183         1
               0       144         244         1
               0       144         305         1
            -100       144          0          1     $ 1 meter DR
            -100       144         61          1
            -100       144         122         1
            -100       144         183         1
            -100       144         244         1
            -100       144         305         1
            -200       144          0          1     $ 2 meter DR
            -200       144         61          1
            -200       144         122         1
            -200       144         183         1
            -200       144         244         1
            -200       144         305         1
c
c         trailer side dose rate traverses
c
f15:p   $      X         Y          Z         R0     $ Rear corner of trailer
               0         0          0          1     $ Contact DR
               0         0         61          1
               0         0         122         1
               0         0         183         1
               0         0         244         1
               0         0         305         1
               0      -100          0          1     $ 1 meter DR
               0      -100         61          1
               0      -100         122         1
               0      -100         183         1
               0      -100         244         1
               0      -100         305         1
               0      -200          0          1     $ 2 meter DR
               0      -200         61          1
               0      -200         122         1
               0      -200         183         1
               0      -200         244         1
               0      -200         305         1
f25:p   $      X         Y          Z         R0     $ mid non src, side trlr
             625         0          0          1     $ Contact DR
             625         0         61          1
             625         0         122         1
             625         0         183         1
             625         0         244         1
             625         0         305         1
             625      -100          0          1     $ 1 meter DR
             625      -100         61          1
```

```
              625      -100      122       1
              625      -100      183       1
              625      -100      244       1
              625      -100      305       1
              625      -200       0        1    $ 2 meter DR
              625      -200      61        1
              625      -200      122       1
              625      -200      183       1
              625      -200      244       1
              625      -200      305       1
f35:p   $      X         Y        Z        R0   $ backend of src, side trlr
             1248       0         0        1    $ Contact DR
             1248       0        61        1
             1248       0        122       1
             1248       0        183       1
             1248       0        244       1
             1248       0        305       1
             1248      -100       0        1    $ 1 meter DR
             1248      -100      61        1
             1248      -100      122       1
             1248      -100      183       1
             1248      -100      244       1
             1248      -100      305       1
             1248      -200       0        1    $ 2 meter DR
             1248      -200      61        1
             1248      -200      122       1
             1248      -200      183       1
             1248      -200      244       1
             1248      -200      305       1
f45:p   $      X         Y        Z        R0   $ mid src, side trlr
             1705       0         0        1    $ Contact DR
             1705       0        61        1
             1705       0        122       1
             1705       0        183       1
             1705       0        244       1
             1705       0        305       1
             1705      -100       0        1    $ 1 meter DR
             1705      -100      61        1
             1705      -100      122       1
             1705      -100      183       1
             1705      -100      305       1
             1705      -200       0        1    $ 2 meter DR
             1705      -200      61        1
             1705      -200      122       1
             1705      -200      183       1
             1705      -200      244       1
             1705      -200      305       1
f55:p   $      X         Y        Z        R0   $ frontend src, side trlr
             2162       0         0        1    $ Contact DR
             2162       0        61        1
             2162       0        122       1
             2162       0        183       1
             2162       0        244       1
             2162       0        305       1
             2162      -100       0        1    $ 1 meter DR
             2162      -100      61        1
             2162      -100      122       1
             2162      -100      183       1
             2162      -100      244       1
             2162      -100      305       1
             2162      -200       0        1    $ 2 meter DR
             2162      -200      61        1
             2162      -200      122       1
             2162      -200      183       1
             2162      -200      244       1
             2162      -200      305       1
f65:p   $      X         Y        Z        R0   $ front corner of trailer
             2300       0         0        1    $ Contact DR
             2300       0        61        1
             2300       0        122       1
             2300       0        183       1
             2300       0        244       1
             2300       0        305       1
             2300      -100       0        1    $ 1 meter DR
             2300      -100      61        1
             2300      -100      122       1
             2300      -100      183       1
             2300      -100      244       1
             2300      -100      305       1
             2300      -200       0        1    $ 2 meter DR
             2300      -200      61        1
             2300      -200      122       1
             2300      -200      183       1
```

```
          2300     -200     244      1
          2300     -200     305      1
f75:p  $    X        Y        Z      R0    $ end trlr thru truck
          2317      144       0      1     $ Contact DR
          2317     144      61       1
          2317     144      122      1
          2317     144      183      1
          2317     144      244      1
          2317     144      305      1
          2417      144       0      1     $ 1 m DR
          2417     144      61       1
          2417     144      122      1
          2417     144      183      1
          2417     144      244      1
          2417     144      305      1
          2517      144       0      1     $ 2 m DR
          2517     144      61       1
          2517     144      122      1
          2517     144      183      1
          2517     144      244      1
          2517     144      305      1
fc85     Truck Driver dose rate: 3' left of CL, 5' ahead of trlr
f85:p     2469      235      122      1
          2469      235      183      1
          2469      235      244      1
          2469      235      310      1     $ level with src
```

CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

DOCUMENT REVIEWED
NUMBER: WHC-SD-TP-ANAL-007
TITLE: SHIELDING ANALYSIS OF THE LONG LENGTH CONTAMINATED EQUIPMENT TRANSPORTATION PACKAGE

Reviewer(s): R. L. Simons

I. Method(s) of Review

- (✓) Input data checked for accuracy
- ( ) Independent calculation performed
- ( ) Hand calculation
- ( ) Alternate computer code: ____
- ( ) Comparison to experiment or previous results
- ( ) Alternate method (define) ____

II. Checklist (either check or enter NA if not applied)

- (✓) Task completely defined
- (✓) Activity consistent with task specification
- (✓) Necessary assumptions explicitly stated and supported
- (✓) Resources properly identified and referenced
- (✓) Resource documentation appropriate for this application
- (✓) Input data explicitly stated
- (✓) Input data verified to be consistent with original source
- (✓) Geometric model adequate representation of actual geometry
- (✓) Material properties appropriate and reasonable
- (NA) Mathematical derivations checked including dimensional consistency
- (NA) Hand calculations checked for errors
- (✓) Assumptions explicitly stated and justified
- (✓) Computer software appropriate for task and used within range of validity
- (NA) Use of resource outside range of established validity is justified
- (NA) Software runstreams correct and consistent with results
- (✓) Software output consistent with input
- (NA) Results consistent with applicable previous experimental or analytical findings
- (✓) Results and conclusions address all points and are consistent with task requirements and/or established limits or criteria
- (✓) Conclusions consistent with analytical results and established limits
- (✓) Uncertainty assessment appropriate and reasonable
- (NA) Other (define) ____

III. Comments: ____

IV. REVIEWER: Robert L. Simons 4-22-96

CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

DOCUMENT REVIEWED
NUMBER: WHC-SD-TP-ANAL-007
TITLE: SHIELDING ANALYSIS OF THE LONG LENGTH CONTAMINATED EQUIPMENT TRANSPORTATION PACKAGE

Reviewer(s): D. E. Lessor

I. Method(s) of Review

- (x) Input data checked for accuracy
- ( ) Independent calculation performed
  - ( ) Hand calculation
  - ( ) Alternate computer code: ______
- ( ) Comparison to experiment or previous results
- (x) Alternate method (define) *All aspects of the writing and included numbers checked for correctness.*

II. Checklist (either check or enter NA if not applied)

- (NA) Task completely defined
- (NA) Activity consistent with task specification
- (NA) Necessary assumptions explicitly stated and supported
- (x) Resources properly identified and referenced
- (NA) Resource documentation appropriate for this application
- (x) Input data explicitly stated
- (x) Input data verified to be consistent with original source
- (NA) Geometric model adequate representation of actual geometry
- (NA) Material properties appropriate and reasonable
- (NA) Mathematical derivations checked including dimensional consistency
- (x) Hand calculations checked for errors
- (x) Assumptions explicitly stated and justified
- (x) Computer software appropriate for task and used within range of validity
- (NA) Use of resource outside range of established validity is justified
- (x) Software runstreams correct and consistent with results
- (x) Software output consistent with input
- (NA) Results consistent with applicable previous experimental or analytical findings
- (NA) Results and conclusions address all points and are consistent with task requirements and/or established limits or criteria
- (NA) Conclusions consistent with analytical results and established limits
- (NA) Uncertainty assessment appropriate and reasonable
- ( ) Other (define) ______

III. Comments: ______

IV. REVIEWER: *D. E. Lessor* *4/17/96*

DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	Nuclear Physics and Shielding	Date May 6, 1996
Project Title/Work Order		EDT No. 603245
Shielding Analysis of the Long Length Contaminated Equipment Transportation Package		ECN No. NA

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
J. G. Field	G1-11	X			
J. R. Green	G1-11	X			
J. Greenborg (2 copies)	H0-35	X			
W. A. McCormick	G1-11	X			
J. V. Nelson	H0-35	X			
A. L. Ramble	A3-38	X			
R. L. Simons	H0-35	X			
R. E. Traister	B3-63	X			
E. M. Veith	H5-68	X			
Central Files (original +3)	A3-88 KN	X			