ORNL/TM-2000/1

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Analysis of the Radiation Fallout Tests at ETBS, France (Fall 1996)

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MANAGED AND OPERATED BY
LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

ORNL-27 (3-96)

ORNL/TM-2000/1

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Date published: January 2000

Prepared by the
Oak Ridge National Laboratory
Oak Ridge, TN 37831-6363
Managed by
Lockheed Martin Energy Research Corp.
for the
U.S. Department of Energy
under contract DE-AC05-96OR22464

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Abstract

1. Introduction

A series of experiments were carried out at the *Etablissement Technique de Bourges* (*ETBS*), France to measure protection factors for the Russian T72M tank during exposure to gamma radiation emanating from the ground (1). The purpose of these measurements was to determine the reduction in the dose rate to the tank occupants when the vehicle traverses terrain that has been contaminated as the result of fallout from a nuclear weapon or when the ground has been contaminated by the distribution of radioactive material by terrorists.

This report summarizes results of calculations that replicate the measurements. Comparisons of measured and calculated protection factors are reported for a series of nested iron cylinders and the T72M tank. The cylinder measurements were performed to compare protection factors measured at Bourges with those obtained previously at the US Army Aberdeen Test Center (2).

2. Details of the Measurements

Measurements were carried out on an 80 m x 80 m field at the *Terrain d'appendage* site at *ETBS*. To simulate fallout, the field was sprayed with ^{140}La ($T_{1/2}$ = 40.27h). The decay gamma-ray spectrum from ^{140}La is given in Table 1. The radioisotope was in the form of $(La)_2\ CO_3$ suspended in water. The field was sprayed on two occasions (29 Oct 1996 – 12.5 MBq/m^2 and 4 Nov 1996 - 19.0 MBq/m^2) to yield a net activity level of 20.1 MBq/m^2 (corrected to 0800 hours 4 Nov 1996). The net activity is less that the sum due to decay of the radioisotope.

Table 1. Decay Gamma-Ray Emission Spectrum from ^{140}La

Energy (MeV)	Emission Rate (%)
1.596	95.40
0.487	45.90
0.816	23.64
0.329	20.74

Lanthanum was selected to simulate the fallout field since it has an average gamma-ray energy that is similar to that of ^{60}Co which was used in earlier tests at the US Army

Aberdeen Test Center[2]. The advantage of using ^{140}La is that the half-life is long enough to perform the measurements and short enough so there is no trace of activity in the soil after ~1 month.

Free-field measurements were made at the center of the field using a 5.08-cm x 5.08-cm NaI detector and a Philips Model No. Zp1220 GM counter each placed at 1 m above the ground. The measured free-field dose rate at the center of the field taking into account corrections for ^{140}La decay was 10.91 mrem/h.

Measurements of the protection factors for the nested iron cylinders and the T72M tank were also made at the center of the irradiated field.

3. Details of the Calculations and Results

The calculated results were obtained using the MASH v2.0 Code System[3] . The two dimensional discrete ordinates code DORT was used to calculate the gamma ray fluence on a coupling surface surrounding the test assemblies. The Adjoint Monte Carlo methods was then used to estimate the dose rate importance of the surface fluence. A processing code folded the fluence with the dose rate importance and generated the desired responses and protection factors.

The DORT calculations were run in R-Z geometry with the 80-m x 80-m field being modeled as a 40-m-radius surface. The ^{140}La source was distributed in the soil in a 0.3-cm-thick layer to account for the penetration of the sprayed liquid into the soil. Sensitivity calculations were performed to compare the free-field dose rate at the center of the field as a function of the source layer thickness. The 40-m-radius surface was divided into 27 radial intervals each with an average source strength of 20.1 MBq/m^2. The air above the soil layer was modeled using 87 intervals extending to 2000 m.

The transport calculations were carried out using the DABL69 (46n,23γ) cross-section library [4]. The compositions of the air and soil used in the DORT calculations are given in Table 2. Also included in the table is the composition of the iron used in the analysis of the nested cylinder measurements.

Table 2. Composition of Materials Used in the DORT Calculation

Element	Air	Ground	Iron Cylinders
Atomic Density (cm^{-3})			
H		9.57 x 10^{-3}	
C			7.82 x 10^{-4}
N	4.19 x 10^{-5}		
O	1.13 x 10^{-5}	3.48 x 10^{-2}	
Al		4.88 x 10^{-3}	
Si		1.16 X 10^{-2}	
Ar	2.51 X 10^{-7}		
Mn			3.88 x 10^{-4}
Fe			8.40 x 10^{-2}

The experimentalists did not provide information about the meteorological or soil conditions at the time of the measurements. The air composition corresponds to that at standard temperature and pressure and with no water vapor. The ground is assumed to be dry.

A 226-direction quadrature set with a minimum polar angle cosine of 0.00544 and a line-of-sight distance of 183.8 m for calculation of the uncollided flux was adopted here. The use of this quadrature set for fallout field and radiological threat analyses was previously determined by Johnson, Santoro and Smith(5) to be optimum for this kind of application.

Free-field dose rates measured and calculated at 1.0 m above the ground surface are summarized in Table 3. The measured and calculated data agree within 3%.

Table 3. Comparison of Measured and Calculated Free-Field Dose Rates

Free Field Dose (mrem/h)	
Measured	10.91
Calculated	10.60
C/M	0.97

Iron Cylinder Protection Factors

The iron cylinders are 75 cm high with a maximum outer dimension of 100 cm. Iron plates were used to close the top and bottom of the cylinders. During the measurements, the cylinders were placed on a steel frame that was 75 cm long by 75 cm wide and 50 cm high. The detectors (NaI and GM) were placed inside the can at 100 cm above the ground corresponding to the same height used for the free-field measurements. A nested cylinder configuration was used to vary the wall thickness. Four cylinder configurations were studied: 10-10-10, 6-6-6, 2-6-6, and 2-2-2. The notation indicates the thickness of the top plate, wall and base plate.

The calculated protection factors for the four cylinder configurations are compared with measured values in Table 4. The calculated protection factors vary by as much as 23% with the NaI data and by as much as 46% with the GM measurements. The NaI detector measurements yield higher protection factors than the GM counter. This trend was also observed in the measurements for the T72M tank discussed below.

Table 4. Protection Factors for the Iron Cylinders

Configuration	NaI	GM	Calculated	C/NaI	C/GM
10-10-10	26	21.9	32	1.23	1.46
6-6-6	7.1	6.2	7.1	1.00	1.15
2-6-6	5.7	4.8	6.6	1.16	1.38
2-2-2	2.2	2.1	1.8	0.82	0.86

T72M Tank Protection Factors

Protection factors for the commander and driver of the T72M tank were calculated for the case when the tank is at the center of the activated field. The tank geometry and composition was provided by the National Ground Intelligence Center. Protection factors for the commander and gunner's head locations were calculated for the condition with the vehicle hatches closed. Measurements were made at other crew locations with the tank hatch open. Since the intention of this analysis was to demonstrate that the MASH code system is applicable for determining protection factors for a simulated fallout field and because the code running times for the complex T72M geometry are long, the comparisons given here are sufficient.

The measured and calculated protection factors for the commander and driver's head locations are compared in Table 5. Tissue dose rates were calculated at the actual locations of the two head positions. These were both higher above the ground than the height at which the free field dose rate was measured. The measured and calculated protection factors were determined from the ratio of the dose rate at the head locations divided by the free-field dose rate at 1 m.

Table 5. Protection Factors for the T72M Tank

Configuration	NaI	Calculated	GM	C/NaI	C/GM
	Hatch Closed				
Commander's Head	49.1	47.3	35.50	0.96	1.33
Gunner's Head	50.1	42.5	42.80	0.85	0.99

The calculated protection factors are in good agreement with the NaI measurements at the commander's head location and differs by 15% at the gunner's head. The agreement with the GM measurements is 33% high at the commander's location and in good agreement at the gunner location. As for the iron cylinder measurements, the NaI results are higher than the GM data.

4. Conclusions

The potential of the MASH Code System in estimating protection factors for a radiological source on the surface of the ground was demonstrated in Ref. 5. The results obtained in this work benchmark the calculational results with measured data. The ratios of the calculated and measured data are quite acceptable and comparable with the differences between the NaI and GM results.

Different protection factors are reported for the NaI and GM measurements in most of the experiments reported in Ref. 1. While these authors believe the NaI results to be more reliable, the experimentalists should resolve the disparity between the NaI and GM data.

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