FALLOUT RADIATION
PROTECTION PROVIDED BY
TRANSPORTATION VEHICLES

20 OCTOBER 1972

MASTER

~~DISTRIBUTION OF THIS DOCUMENT IS LIMITED
To AEC Offices and AEC Contractors~~

LAS VEGAS AREA OPERATIONS
EG&G, INC., 680 E. SUNSET RD., LAS VEGAS, NEV. 89109

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

EGG 1183-1566
Technical Report No. L-1075
20 October 1972

FALLOUT RADIATION PROTECTION PROVIDED BY TRANSPORTATION VEHICLES

By

Z. G. Burson

NOTICE

This report contains information of a preliminary nature and was prepared primarily for internal use at the originating installation. It is subject to revision or correction and therefore does not represent a final report. It is passed to the recipient in confidence and should not be abstracted or further disclosed without the approval of the originating installation or DTI Extension, Oak Ridge.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

work
ther
ergy
y of
ees,
any
com-
atus,
s use

Approved for Publication:

C. P. Jupiter, Manager

Radiation and Environmental Sciences Department

This Document is
UNCLASSIFIED

G. P. Stobie
Classification Officer

MASTER

~~DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED~~

Prepared for the U. S. Atomic Energy Commission Under Contract No. AT(29-1)-1183.

~~DISTRIBUTION OF THIS DOCUMENT IS LIMITED~~
~~To AEC Offices and AEC Contractors~~

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

ABSTRACT

Fallout radiation protection factors (PF's) were estimated for a variety of civilian transportation vehicles using measurements of the natural terrain radiation as a source. The PF values are below 2 in light vehicles, truck beds, or trailers; from 2.5 to 3 in the cabs of heavy trucks and in a railway guard car; and from 3.0 to 3.5 in the engineer's seat of heavy locomotives. This information can be useful in planning the possible movement of personnel from or through areas contaminated either by a wartime incident or a peacetime accident. The information may also be useful for studying the reduction of exposure to the natural terrestrial radiation environment provided by vehicles.

CONTENTS

	<u>Page</u>
ABSTRACT	ii
1. INTRODUCTION	1
2. EXPERIMENTAL METHOD	2
3. RESULTS	6
3.1 Cars and Trucks	6
3.2 Train Engine and Coach	6
4. SUMMARY	16
REFERENCES	18

ILLUSTRATIONS

<u>Figure</u>	<u>Page</u>
1 Pulse height distribution comparisons from natural terrain radiation	3
2 Crew cab	9
3 Carryall	9
4 2-1/2 ton truck	10
5 5 ton truck	10
6 Heavy truck (tractor with trailer)	11
7 Firetruck	11
8 Railway guard car	12
9 Switch engine	12
10 Railway guard car, bunk area	14
11 Railway guard car, kitchen area	14
12 Heavy locomotive	15

TABLES

<u>Table</u>	<u>Page</u>
1 Method of protection factor calculation using measure- ments from natural terrain radiation 	4
2 Reduction of spectral components of natural terrestrial radiation in cars and trucks, gonad position 	7
3 Reduction of spectral components using natural terrain radiation 	13
4 Fallout radiation protection factors provided by civilian vehicles 	17

1. INTRODUCTION

The shielding against gamma rays from radioactive fallout provided by barriers of all types has been studied in detail during the decade of the 1960's.⁽¹⁾ These studies included calculational techniques,⁽²⁾ and the experimental data on barriers,⁽³⁾ structures,⁽⁴⁾ and military vehicles.⁽⁵⁾ To make these studies more nearly complete, the USAEC requested that experimental measurements be made of the fallout radiation protection provided by civilian transportation vehicles normally used to transport personnel. The information would be useful for planning the possible movement of personnel from or through areas contaminated either by a wartime event or a peacetime accident. Another purpose was to provide some basic information necessary to document the effects of nuclear weapons; this will be included in the revision of the unclassified book, "The Effects of Nuclear Weapons".⁽⁶⁾

Initially, measurements were taken in two commercial buses and a school bus.⁽⁷⁾⁽⁸⁾ An infinite plane of ^{60}Co was simulated by hydraulically pumping a ^{60}Co source at a uniform speed through plastic tubing spread in a uniform manner under and around the vehicles.

Later, a method was developed by which the natural radiation existing in the soil was used as the radiation source to determine the protection factors. Measurements were then made on a variety of vehicles, including a railroad locomotive and coach.

This report covers the measurements made using the natural terrain radiation. It also includes the data for the buses for informational purposes. Some attempts were made at calculations using the Engineering Manual Method.⁽²⁾ However, because of the uncertainty of mass distribution, it soon became apparent that the calculations were impractical, indicating the need for experimental measurements.

2. EXPERIMENTAL METHOD

The exposure-angle distributions above fallout fields have been measured⁽⁹⁾ and calculated.⁽¹⁰⁾ The isotope of ^{60}Co can be used to create the correct exposure angle distribution on the outside of the shield.⁽¹¹⁾ The transport of radiation emitted from isotopes naturally occurring in the soil (^{40}K , Uranium and Thorium Series) is not too different from that of 1.12 hour fission products or from ^{60}Co . However, since these isotopes are mixed in the soil, the resulting exposure angular distributions appear as an extreme ground roughness case for surface deposition. Nevertheless, it appeared feasible to use the natural terrain radiation by examining the spectrum, both free-field and inside vehicles, to estimate what the protection factors might be for a fallout case.

One of the buses, which had been previously tested by a ^{60}Co simulated infinite plane, was used for the first test. A 20-minute spectrum was accumulated 3 ft above the ground and again in several locations inside the bus. A 4 in. x 4 in. -NaI crystal (unshielded) was used. Data were accumulated in a multi-channel analyzer. Measurements were made in the center of the helicopter pad in Area 28 at NTS. Response measurements⁽¹²⁾ of the crystal from monoenergetic sources indicated its response was nearly isotropic. Single, unshielded 4 in. x 4 in. -NaI crystals have been used for environmental radiation monitoring.⁽¹³⁾

Pulse-height distributions are shown in Figure 1 for the free-field case and a location in the bus. The peaks from ^{40}K and ^{208}Tl are clearly visible. Other peaks are primarily due to the radon daughters existing in the top few centimeters of the soil. For all of the measurements, background contribution due to cosmic radiation was subtracted out. It was assumed that airborne radioactivity was negligible compared to other uncertainties. This is probably valid, since the terrestrial radiation levels at this location are very high (greater than $15\mu\text{ R/hr}$).

The intent was not to measure the protection directly, but to determine empirically a method of analysis that could be used to estimate a fallout protection factor.* Several methods of data reduction were tried. These are listed in Table 1 for several positions in the bus.

Also listed in Table 1 are the protection factors derived from the ^{60}Co experiment on the same bus.⁽⁷⁾⁽⁸⁾ The spread of this data represents the uncertainty when applied to fallout. The method of analysis of using the counts under the ^{40}K peak plus the counts in the multiple scatter peak channel (around 80 keV) produces PF values very close to those from the ^{60}Co experiment.

*Fallout protection factor (PF) is defined as the ratio of the exposure rate 3 ft above an infinite smooth plane of 1 hour fission products to the exposure rate at the point in question.

Figure 1. Pulse height distribution comparisons from natural terrain gamma radiation - single 4 inch x 4 inch NaI detector.

Table 1. Comparison of protection factors using different methods.

	<u>Method</u>	<u>Rear seat gonad position</u>	<u>Rear seat chest position</u>	<u>Center 3 ft</u>	<u>Driver gonad position</u>
1.	Gross count only	2.12	1.78	1.47	1.74
2.	Counts x channel number	2.25	1.90	1.53	1.76
3.	Peak channel (~80 keV)	1.95	1.56	1.37	1.77
4.	^{40}K peak area	2.59	2.08	1.57	1.87
5.	Net ^{40}K area	2.95	2.27	1.68	2.02
6.	^{208}Tl peak area	2.41	1.92	1.48	1.71
7.	Net ^{208}Tl area	2.10	1.71	1.34	1.53
8.	^{40}K peak area + peak channel	2.09	1.67	1.41	1.79
	^{60}Co experiment	1.9-2.0	1.5-1.7	1.5-1.7	1.8-2.1

The angular distribution of the uncollided radiation arriving at a detector 3 ft above an infinite smooth plane of fallout radiation is strongly peaked in the horizontal direction, indicating that radiation originating at large distances contribute heavily to the exposure rates. This is not so for natural terrain radiation. Since the isotopes are distributed in the soil, radiation originating at large distances must penetrate much soil to arrive at a detector 3 ft above the ground as uncollided radiation. Consequently, the angular distribution of the uncollided component is not nearly as peaked in the horizontal direction as for fallout on a smooth plane. Furthermore, most of this radiation reaching the detector has originated near the detector.

Note that the attenuation for the peak areas of the rear seat position is high, and for the center position, low. The bus engine is located below the rear seat, providing much attenuation at this location.

The scattered-to-direct ratio should be much greater for natural terrain radiation than for fallout on a smooth plane. The multiple and the ^{40}K peak at 1.46 MeV can represent the uncollided radiation. One would expect, then, that some combination of analysis methods using these two components could be used to imply PF values for a fallout radiation situation.

In every vehicle measured, the spectrum was examined carefully to see if any sources of radiation existed within the vehicles themselves. Only one vehicle indicated an internal source. Trace amounts of ^{60}Co were observed on one NTS truck which had been used to transport radioactive material. It was assumed that contributions from any natural isotopes (^{40}K , U or Th) existing inside the vehicles were negligible.

3. RESULTS

3.1 CARS AND TRUCKS

Using the method described in Chapter 2, measurements were made in a variety of cars, pickups, and trucks. The natural terrain radiation was used as a source and the location was at the helicopter pad in Area 28 (BREN Tower site) at the NTS. Spectra were accumulated for 20 minutes each at one or more locations in each vehicle. The reduction of the radiation components were calculated and are given in Table 2. Photographs of each vehicle are shown in Figure 2 thru 7. The resulting protection factors applicable to an infinite smooth plane of fallout radiation are also given on each figure for that vehicle. The method of analysis of gross counts under the ^{40}K peak plus a peak channel (80 keV) was used as a primary guide with a little judgment as to the location in relation to any massive shielding nearby.

Trace amounts of ^{60}Co were detected in the 5-ton truck. Therefore, only the ^{40}K peak data were used as a guide, plus results of other similar vehicles.

3.2 TRAIN ENGINE AND COACH

A small switching locomotive and special railway guard car were tested at Nellis Air Force Base. The railway guard car is used to transport special military related personnel over commercial railroads. It is completely equipped to be self sufficient. The car is divided into three sections (Figure 8).

The front section contains the kitchen, dining area, shower and toilet facilities. The center section contains nine folding bunks and a wardrobe closet. The third section contains a diesel generator set, air conditioning unit, hot water heater and all electrical controls.

The measurements were made on a railroad spur in the desert near Nellis AFB about 300 ft from the nearest building.

Pulse-height distributions were accumulated for 2,000 seconds (33-1/3 min) at several locations in the guard car, one location in the switching engine and a few locations 3 ft above the ground nearby (without the car or engine present). Measurements were also made in a large locomotive (engineer's seat) at the Union Pacific Railroad yard in Las Vegas. The same procedures were used.

Table 2. Reduction factor of spectral components of natural terrestrial radiation in cars and trucks, gonad position.

<u>Vehicle</u>	<u>Position</u>	<u>Peak Channel*</u> <u>(~80 keV)</u>	<u>⁴⁰K**</u> <u>Peak</u>	<u>Gross Counts***</u> <u>Under ⁴⁰K Peak</u>	<u>Gross Counts in ⁴⁰K</u> <u>Peak Plus Peak Channel</u>
Passenger Car	Passenger Side (chest)		1.59	1.42	
	Driver Side		1.53	1.34	
Pickup	Driver Side	2.29	1.73	1.64	2.01
Crew Cab	Driver Side	2.05	1.70	1.55	1.84
	Back Seat	2.26	1.59	1.53	1.93
Carryall	Driver Side	2.11	1.55	1.48	1.84
	Rear Seat	1.97	1.73	1.65	1.85
2-1/2 Ton Truck	Driver Side	2.11	1.79	1.64	1.92
	Center of Bed	1.43	1.85	1.70	1.52
5 Ton Truck	Driver Side		2.00		
	Sleeper		1.95		
Heavy Truck	Driver Side	2.78	2.64	2.38	2.63
	Center of Trailer	1.37	1.77	1.64	1.46
Fire Truck	Driver Side	3.17	2.84	2.62	2.96
	Standing Area in Back	1.88	1.64	1.59	1.77

*Using the counts in a single channel (~80 keV).

**Using the counts in a single channel at 1.46 MeV.

***Summing the counts in several channels under the photo peak area.

Results of the measurements are given in Table 3. Photographs are shown and protection factors indicated in Figures 9 through 12.

The protection factor at the engineer's location in both the switch engine and the heavy locomotive is estimated to be between 3.0 and 3.5. One might expect more protection than this. However, a simplified calculation using reference 2 yielded a PF of about 3. While much shielding material existed below, in front and behind the detector, very little existed on the sides. Raising the detector from 3 ft to 10 ft only decreases its responses about 10% (fallout on rough ground).⁽⁹⁾

Figure 2. Crew cab. Fallout radiation protection factor 1.8 to 2.0.

Figure 3. Carryall. Fallout radiation protection factor 1.7 to 1.9.

Figure 4. 2-1/2 ton truck. Fallout radiation protection factor for driver, 1.8 to 2.0; in truck bed, 1.4 to 1.6.

Figure 5. 5 ton truck. Fallout radiation protection factor for driver 2.0 to 2.2; in sleeper, 1.9 to 2.1.

Figure 6. Heavy truck (tractor with trailer). Fallout radiation protection factor for driver, 2.4 to 2.8; in center of trailer, 1.4 to 1.6.

Figure 7. Firetruck. Fallout radiation protection factor for driver, 2.7 to 3.1; standing area in back, 1.6 to 1.8.

Figure 8. Railway guard car.

Figure 9. Switch engine. Fallout radiation protection factor for engineer, 3.0 to 3.5.

Table 3. Reduction factor of gamma energy spectral components from natural terrain radiation by various vehicles.

<u>Vehicle</u>	<u>Location</u>	<u>Gross Count</u>	<u>Peak Channel</u>	<u>^{40}K Peak</u>	<u>Gross Count Under ^{40}K Peak</u>	<u>Net Counts Under ^{40}K Peak</u>	<u>Peak Channel Plus ^{40}K Peak Area (gross)</u>
Switch Engine	Engineer's Seat	2.6	3.7	3.1	2.6	3.6	3.2
Guard Car	Center Bunk	1.9	2.8	2.1	1.9	2.2	2.4
	On Table	2.0	2.8	2.5	2.2	2.6	2.6
	On Couch	1.9	2.4	1.9	1.9	2.0	2.2
Heavy Locomotive	Engineer's Seat	3.0	4.2	1.9	1.9	1.9	3.3

Figure 10. Railway guard car, bunk area. Fallout radiation protection factor, 2.2 to 2.6.

Figure 11. Railway guard car, kitchen area. Fallout radiation protection factor on table, 2.4 to 2.8; on couch, 2.0 to 2.4.

Figure 12. Heavy locomotive. Fallout radiation protection factor for engineer, 3.0 to 3.5.

4. SUMMARY

Fallout radiation protection factors were estimated for a variety of civilian transportation vehicles.

Initially, measurements were made in commercial buses from a simulated infinite plane of ^{60}Co . Later, measurements were repeated in one of the buses using the natural radiation existing in the soil as a source. A 4 in. x 4 in. -NaI crystal was used as the detector. An empirical relationship was obtained between the ^{60}Co measurements and those from natural terrain radiation. Measurements were then made on a variety of vehicles, including railroad locomotive and a coach. The results are summarized in Table 4. This information can be useful in planning the possible movement of personnel from or through areas contaminated either by a wartime event or a peacetime accident. The information may also be useful for studying the reduction of the natural terrestrial radiation environment provided by transportation vehicles.

Table 4. Fallout radiation protection factors provided by civilian vehicles.

<u>Vehicle</u>	<u>Position</u>	<u>Protection Factor Range</u>
Commercial Bus (common type)	Throughout bus	1.4 to 2.1
Commercial Bus (scenic cruiser type)	Throughout bus	1.4 to 2.1
School Bus	Throughout bus	1.5 to 1.8
Passenger Car	Passenger side (chest) driver side	1.5 to 1.7 1.5 to 1.7
Pickup	Driver side	1.9 to 2.1
Crew Cab	Driver side Back seat	1.8 to 2.0 1.8 to 2.0
Carryall	Driver side Rear seat	1.7 to 1.9 1.7 to 1.9
2-1/2-ton Truck	Driver side Center of bed	1.8 to 2.0 1.4 to 1.6
5-ton Truck	Driver side Sleeper	2.0 to 2.2 1.9 to 2.1
Heavy Truck	Driver side Center of trailer	1.4 to 1.6 2.7 to 3.1
Fire Truck	Driver side Standing area in back	2.7 to 3.1 1.6 to 1.8
Switch Engine	Engineer's seat	3.0 to 3.5
Railway Guard Car	Sleeping quarters Kitchen area Center area	2.2 to 2.6 2.4 to 2.8 2.0 to 2.4
Heavy Locomotive	Engineer's seat	3.0 to 3.5

REFERENCES

1. Radiation Shielding, Analysis and Design Principles as Applied to Nuclear Defense Planning. TR-40, Office of Civil Defense and Kansas State University, November 1966.
2. "Design and Reviews of Structures for Protection from Fallout Gamma Radiation," PM-100-1, Office of Civil Defense, February 1965.
3. Burson, Z. G., and Summers, R. L., "Barrier Attenuation of Air-Scattered Gamma Radiation," CEX-63.3, Civil Effects Test Operations, U. S. Atomic Energy Commission, June 1965.
4. Burson, Z. G., "Experimental Evaluation of the Fallout-Radiation Protection Provided by Structures in the Control Point Area of the Nevada Test Site," CEX-69.5, Civil Effects Test Operations, U. S. Atomic Energy Commission, October 1970.
5. Schmoke, M. A. and Bolin, L. R., "Fallout Shielding Characteristics of Combat Vehicles, M125A Self-Propelled Mortar, M678 Recovery Vehicle, M41 Tank," BRL Report No. 1555, U. S. Army Ballistics Research Laboratories, October 1971.
6. The Effects of Nuclear Weapons, U. S. Atomic Energy Commission, April 1962.
7. Summers, R. L., "Experimental Measurements of Fallout Protection Provided by Transportation Vehicles," EGG-1183-1334, 30 June 1967.
8. Summers, R. L. and Burson, Z. G., "Radiation Protection Provided by Standard Passenger Buses" Health Physics, Vol. 18, p. 87, 1970.
9. Huddleston, et al, "Ground Roughness Effects on the Energy and Angular Distribution of Gamma Radiation from Fallout" Health Physics Vol. 11, pp. 537-548, 1965.
10. Spencer, L. V., "Structure Shielding Against Fallout Radiation from Nuclear Weapons" NBS Monograph 42, National Bureau of Standards, June 1962.
11. Burson, Z. G. and French, R. L., "Simulating Energy and Angle Distributions Above Infinite Plane Cobalt-60 Sources" Health Physics, Vol. 18 (May 1970), pp. 507-521.

12. Fritzsche, A. E., EG&G, Personal Communications.
13. Beck, H. L., et al, (HASL-USAEC) "In Situ External Environmental Gamma Ray Measurements Utilizing Ge(Li) and NaI(Tl) Spectrometry and Pressurized Ionization Chambers." Paper presented at the International Symposium on Rapid Methods for Measuring Radioactivity in the Environment, Neuherberg, Federal Republic of Germany, 5-9 July 1971.

DISTRIBUTION

AEC/NVOO

J. Koch
R. Loux
R. Purcell

DTIE

P. Rosser (2)

EG&G, Las Vegas

Z. Burson (45)