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14. ABSTRACT

This TOP describes the techniques, procedures, and general outline required to determine the RADIAC Correlation Factor to estimate the external environment from an internal measurement. Test/Analysis preparation, execution, and documentation are covered in this TOP.

15. SUBJECT TERMS

RADIAC fallout/ contamination correlation

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US ARMY DEVELOPMENTAL TEST COMMAND
TEST OPERATIONS PROCEDURE

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DTIC AD No.

RADIOACTIVITY, DETECTION, INDICATION, AND COMPUTATION (RADIAC) CORRELATION FACTOR TESTING

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1. SCOPE.

This Test Operations Procedure (TOP) outlines the procedures and facilities necessary to perform a Radioactivity, Detection, Indication and Computation (RADIAC) instrument correlation factor test/analysis. The measurement principles covered in this TOP may be applied to determining the correlation factor of RADIACs installed in major weapon systems and vehicles.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

2.1.1 The selection of the simulation facility required for performing a RADIAC correlation factor test is driven by the test site's approval for radioactive sources.

2.1.2 The following list outlines the types of facility characteristics that will be necessary to perform RADIAC correlation factor testing.

Facility	Requirement
Gamma radiation facility or area	Capability to simulate the gamma radiation produced by the systems external environment, whether from fallout or other contamination. Two sources of gamma are usually used to simulate the fallout environment, Cobalt-60 source (which simulates the early fallout spectrum up to ≈ 4 hours and the late fallout spectrum ≈ + 5 days) and a Cesium-137 source (which simulates the mid-time fallout spectrum between ≈ 4 hours to ≈ 5 days). These two sources also provide the high energy gamma source Co-60 1.17 and 1.32 million electron volts (MeV) and a medium energy gamma source CS-137 660 kilo-electron volts (keV).
Area grid	Capability to setup or provide a measured grid for establishing source location.
Radioactive source handlers	Capability to provide personnel trained in the use and movement of radioactive sources.
Source positioning system	Capability to accurately position the source.
Low level radiation meter	Capability to measure radiation down to and including the area background

2.1.3 The Gamma Radiation Facility (GRF) located at the Survivability, Vulnerability Assessment Directorate (SVAD), White Sands Test Center (WSTC), U.S. Army White Sands Missile Range (WSMR) provides all of the above requirements.

2.2 Instrumentation.

2.2.1 The following list outlines the major environmental parameter measurement requirements, type of measuring device, and the recommended accuracy.

Measurement/Devices for Measuring	Measurement Accuracy
Radiation environment meter (remote computer control/interface)	10 micro-rad per hour (μrad/hr) or 20% of background
Grid position (grid markings or source position, physically or remotely controlled)	± 0.03 meter (m)
RADIAC probe position relative to grid (measured by two intersecting planes)	± 0.03 m
Measurement recording system	Spreadsheet

2.2.2 The facility data instrumentation must be able to record, average, and archive the measured environment on a per grid position basis. The data recording rate (readings per second or minute) must be long enough to average for statistical radiation source variation. The data output can be generated in several formats, and at a minimum, a conversion process to the American Standard Code for Information Interchange (ASCII) must be available to ensure compatibility with data reduction. Typically, the instrumentation requirements for RADIAC correlation factor determination must have a measurement period of approximately 1.5 minutes at a reading rate of 1 per second, thereby producing 90 measurements per grid location, which are averaged to remove radiation statistical variation.

2.2.3 Still photography must be available to document the test setup.

3. REQUIRED TEST CONDITIONS.

3.1 Pre-Test Investigation.

3.1.1 System specific information must be gathered to determine normal configuration and RADIAC probe location.

3.1.2 Test data requirements, instrumentation type, and placement should be established to accurately define the measurement position and measured environment.

3.1.3 Completely functional prototypes or production versions of a test system may not be required for RADIAC correlation testing if the configuration differences are transparent to the test environment. For example, as long as all materials are present in the correct layout, the system does not have to be electrically or mechanically operational.

3.1.4 The selected measurement facility's test grid must be able to accommodate the test item. The SVAD WSTC GRF grid is shown in Figure 1.

Figure 1. SVAD WSTC GRF source grid.

3.1.5 RADIAC correlation factor tests are considered non-destructive.

3.2 Instrumentation Installation.

3.2.1 Radiation environment meter. The radiation environment meter probe is installed in the system such that the probe is located in the same position as the normal RADIAC probe. The RADIAC is left in place, especially if the RADIAC probe is attached to its top side. The radiation environment meter body is placed away from and above the RADIAC probe location and the power and computer interface routed so that they do not affect the environment.

3.2.2 Automated source positioning. An automated source positioning system is desired to increase position repeatability, reduce personnel exposure to radiation, and to allow automated measurements to be performed for one entire row or column of the positioning grid. The WSTC GRF source automated positioning system is shown in Figure 1.

4. TEST PROCEDURES.

RADIAC correlation factor test setup.

a. System position. The system for which the RADIAC correlation will be measured is positioned near the geometric center of the grid (the SVAD WSTC GRF grid is 9 m by 27 m). The system is positioned so that the tires or tracks, etc., allow adequate room for source positioning on the center of each grid square. Figure 2 shows a system positioned for the RADIAC Correlation test.

Figure 2. System positioned for RADIAC correlation.

b. Measurement meter probe position. The radiation environment meter probe is installed in accordance with paragraph 3.2.1.

c. Establish the measurement probe position with respect to test grid. Once the measurement probe is installed, its geometric position (with respect to the test grid) must be established. The position of the RADIAC radiation probe is established by setting a reference point on the grid plane, in line with the measurement probe, and parallel to the grid square. The distance to the probe over two perpendicular planes is then measured (i.e. height and distance from the reference point).

d. Background measurement. At the start of each test measurement day, before the sources are moved into the area, and with the radiation detector in the vehicle, the background radiation dose rate is measured and recorded. The measurements should be taken once per second for 15 minutes. These 900 measurements are averaged and recorded as the in-vehicle background.

e. Source at ground level measurement. The source (either Cobalt-60 or Cesium-137) is placed at a starting grid position (1,1) at ground level, and the readings from the measurement probe are recorded once per second for 1.5 minutes. These readings are then averaged to reduce the statistical source variation and stored digitally, referencing the source type and grid square. This measurement and procedure are repeated until all grid positions have been measured (i.e. grid 1,1 to grid 9,27).

f. Source elevated measurement. The source (either Cobalt-60 or Cesium-137) is positioned at a starting grid position (1,1), and 0.5 m above the ground (this is done to simulate the expected large area covered by the fallout or contamination) as shown in Figure 3. The readings from the measurement probe are recorded once per second for 1.5 minutes. These readings are then averaged to reduce the statistical source variation and stored digitally, referencing the source type and grid square. This measurement and procedure are repeated for the rectangular outer edge of the grid until all grid positions have been measured (i.e. grid (1,1)-(1,27), (2,1)-(8,1), (9,1)-(9,27), and (2,27)-(8,27)).

g. Free field measurements. When all measurement in paragraphs 4.1.1.e and 4.1.1.f are completed, the system is moved from the test area and the measurement probe is placed at the same position as determined in paragraph 4.1.1.c (Figure 4). With the measurement probe in the free field (i.e. no system present) all the measurements in paragraphs 4.1.1.d through 4.1.1.f are repeated and recorded.

h. All test data and results, and pertinent information are archived for retention and data reduction.

Figure 3. Source raised 0.5 m.

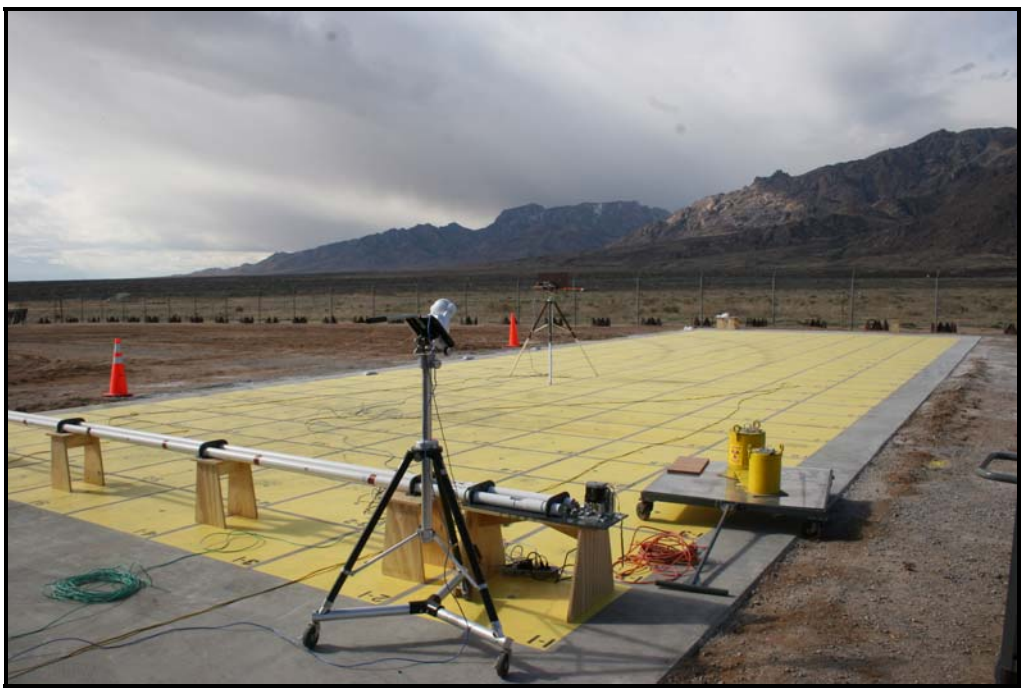

Figure 4. Free field measurements.

5. DATA REQUIRED.

a. Detailed description of the test item (vehicle in which the RADIAC is installed) to include the following:

(1) Serial number.

(2) Serial numbers for subcomponents (if applicable).

(3) Dimensions.

(4) Material composition.

(5) Material safety data sheets (MSDSs) if applicable.

(6) Photograph of pre-test and post-test condition.

b. Description of the test facility and the method used to produce the simulated radiation environment.

c. Detailed description of RADIAC and measurement probe position with respect to grid.

d. Results of the data measurements expressed in radiation absorbed dose per hour (rad/hr); for each source, at each grid square, and height.

e. Calculations used for data reduction:

(1) The internal measurements are adjusted for background by subtracting the averaged internal background reading; if the resulting value is negative a value of zero is assigned to that grid square.

(2) The free field measurements are adjusted for background by subtracting the averaged free field background reading; if the resulting value is negative a value of zero is assigned to the grid square.

(3) From these measurements the gamma protection factor for the RADIAC probe location is calculated by dividing the adjusted free field measurement by the adjusted internal measurement. The resulting protection values are inverted to obtain the transmission factors; these factors are averaged for the ground grid squares and the source elevated readings. This method skews the average toward the system areas that produce the least attenuation of the gamma environment, and calculations that result in infinite values are ignored.

(4) The transmission factors are then weighted to simulate the fallout field. The overall average for the ground grid transmission factors is assigned a weighting factor of 30 percent and the overall average for the source elevated transmission factors is assigned a weighting factor of

70 percent. This weighting is assigned since the fallout/contamination field is expected to be large with respect to the test grid. This results in the following formula:

Overall transmission average = 0.3* ground grid transmission average + 0.7* elevated transmission average

(5) The radiation correlation factor is then calculated by inverting the overall transmission factor:

$$\text{radiation correlation factor} = \frac{1}{\text{Overall transmission average}}$$

f. Archive of photographs of test setup.

g. Test conductor log of all procedures performed.

6. PRESENTATION OF DATA.

Data should be reduced and provided in accordance with the format of US Army Developmental Test Command Pamphlet (DTC PAM) 73-1[1]. Per DTC PAM 73-1, the data should be reduced to tables, graphs, images, and photos where possible.

a. Tables may be used to present the following data:

(1) Equipment test matrix. A sample is provided as Table 1.

TABLE 1. TEST ITEM MATRIX

ITEM	NATIONAL STOCK NUMBER/DESCRIPTION	SERIAL NUMBER	LOCATION
System X	System under test	1	Grid position
Measurement meter	Eberline ERM-2	1	Probe grid position

*Superscript numbers correspond to Appendix C, References.

(2) Tables 2and 3 show examples of grid test point protection factor data.

TABLE 2. COBALT-60 PROTECTION FACTORS

COBALT-60 FICTITIOUS EXAMPLE PROTECTION FACTORS											
		1	2	3	4	5	6	7	8	9	
			130	80	33	43	52	72	64		
1	106	75	93	51	22	41	90	88	72	74	90
2	85	104	74	97	28	35	107	213	76	119	107
3	56	69	90	91	63	34	99	112	64	109	114
4	53	84	82	129	90	75	82	159	94	110	130
5	38	60	71	51	72	222	83	144	89	112	96
6	31	33	57	97	33	114	111	118	73	81	71
7	31	43	44	83	83	120	69	85	56	63	59
8	74	68	63	94	71	157	83	55	44	62	61
9	32	78	74	23	120	136	43	30	46	53	61
10	27	48	49	25	56	98	36	17	27	49	19
11	59	75	162	331	236	419	124	16	32	44	45
12	58	124	166	581	81	176	53	26	31	37	38
13	210	249	439	742	540	597	327	39	41	49	53
14	244	328	448	1886	915	976	387	47	56	68	62
15	365	453	891	10532	6721	1099	703	71	69	84	68
16	404	469	2606	2685	1910	1105	1477	97	90	87	74
17	505	488	2048	4963	1820	1521	1574	82	123	153	106
18	1168	1552	inf	8891	3564	1463	1392	114	154	135	88
19	5634	8564	1113	2791	3119	35251	793	167	218	155	102
20	1381	3794	860	1382	161	inf	493	26	31	19	158
21	2104	2163	1434	1353	779	inf	530	496	494	156	216
22	3436	9314	inf	196	122	inf	543	203	353	250	263
23	inf	1933	427	50	273	inf	3179	233	464	228	263
24	645	2965	178	343	104	23	668	572	601	536	506
25	6653	23302	inf	728	124	187	inf	523	734	385	227
26	9704	2800	165	241	15	inf	inf	1330	inf	345	331
27	226	1290	1144	598	215	1719	1425	991	710	255	2171
			1465	426	73	1410	837	8379	1025		

RADIAC probe location
System outline
Source raised 0.5m

Note: For these generated values, the Cobalt-60 radiation correlation factor was 95.

TABLE 3. CESIUM-137 PROTECTION FACTORS

CESIUM FICTITIOUS EXAMPLE PROTECTION FACTORS											
		1	2	3	4	5	6	7	8	9	
		64	47	89	32	33	47	60	89	88	inf
1	218	73	215	55	24	36	63	60	40	83	87
2	85	33	82	78	26	31	81	72	45	110	79
3	34	47	81	97	58	36	72	84	66	90	81
4	67	50	81	88	77	57	44	48	79	73	151
5	28	45	102	44	82	87	69	102	72	37	71
6	35	20	52	62	21	60	88	160	68	56	100
7	23	29	33	63	60	67	62	83	55	47	51
8	49	73	48	60	44	106	100	46	33	43	45
9	47	63	64	17	80	113	37	47	33	36	44
10	20	20	41	21	49	80	31	11	18	32	12
11	44	62	99	325	147	132	106	11	17	30	32
12	54	78	122	1004	126	153	44	19	22	25	29
13	142	146	395	612	359	381	245	28	28	30	37
14	239	848	583	2342	1334	1157	360	38	39	40	49
15	682	757	inf	inf	inf	753	953	56	59	53	54
16	755	254	inf	963	5265	5996	315	84	61	55	83
17	689	3384	inf	619	inf	135	811	175	104	67	112
18	671	863	inf	2033	638	345	inf	179	145	96	57
19	inf	443	223	inf	704	inf	439	inf	178	107	80
20	54460	452	inf	inf	463	38	inf	717	147	74	468
21	inf	189	170	inf	inf	93	180	inf	280	466	149
22	411	203	150	335	384	3028	93	168	644	185	157
23	1200	218	inf	286	277	inf	inf	250	672	229	inf
24	90	619	163	78	inf	197	1118	inf	inf	inf	282
25	inf	inf	59	inf	217	inf	inf	inf	567	66	inf
26	180	584	241	inf	73	1135	60	130	44	96	inf
27	inf	179	inf	84	2828	inf	inf	inf	614	88	168
		inf	inf	276	189	398	-462	1088	133	211	

RADIAC probe location
System outline
Source raised 0.5m

Note: For these generated values, the Cesium-137 radiation correlation factor was 70.4.

b. Photographs of test setup (Figure 5), or photographs/illustrations that add information, should be included.

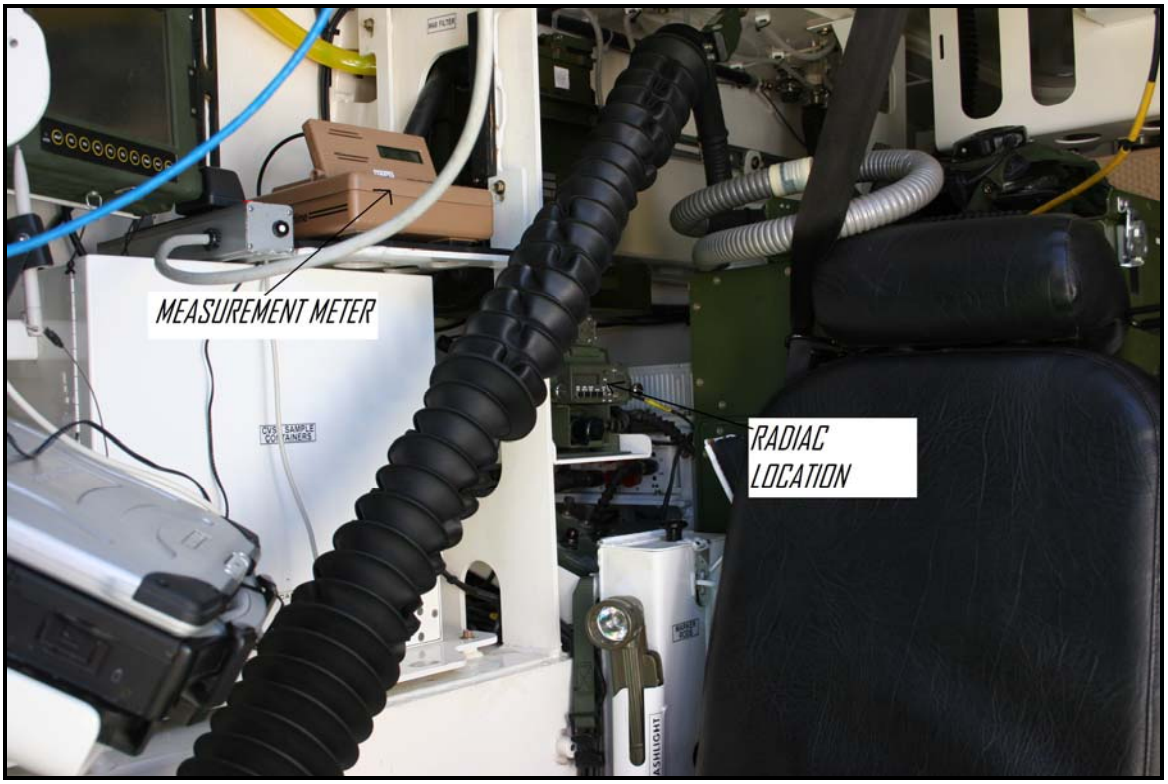

Figure 5. Test setup, showing measurement meter, RADIAC, and probe.

APPENDIX A. EXTRACTS AND INFORMATION FROM ALLIED ENGINEERING PUBLICATION (AEP)-14[2].

1.2 BASIC PHILOSOPHY (CHAPTER 2).

1.2.1 There are several reasons to improve the nuclear radiation protection of military vehicles. Armored fighting vehicles (AFVs) are designed to provide mobile firepower and shock action while protecting their operating crews. Other military vehicles are designed to distribute personnel and supplies rapidly and efficiently throughout the theater of operations, or to perform other special jobs such as moving earth or retrieving tanks. In a nuclear warfare environment, however, the survivability of personnel and electronics in the vehicle to penetrating nuclear radiation is significantly less than the survivability of the vehicle itself to the accompanying blast effects. Specifically, for nuclear yields most likely to be employed in forward areas of the battlespace, most vehicles will be lost as a result of nuclear irradiation of the crew, passengers, and sensitive electronics rather than mechanical damage to the vehicle. Additionally, radiological dispersal weapons (RDW) are directed against personnel, generally during operations other than war. In short, personnel and electronics are the most vulnerable elements of the military vehicle system to nuclear environments. This fact, coupled with the principle of keeping radiation exposure as low as reasonably achievable, drives the need to improve the radiation protection of military vehicles.

1.2.2 The four militarily significant components of nuclear radiation are neutrons, gamma rays, alpha particles, and beta particles. The first two are penetrating in nature and pose a threat even if the individual or susceptible piece of electronics is inside the vehicle. The latter two are non-penetrating in nature and pose a threat to vehicle occupants principally when the radioactivity is aerosolized and inhaled by the individual. Methods of protecting against penetrating and non-penetrating radiation are different from one another. The degrees of protection against all of these radiations are expressed by a "protection factor," which is the ratio of the free-field radiation dose (or dose rate) to the radiation dose (or dose rate) received by personnel or equipment inside the vehicle.

1.2.3 Significant operational benefits can accrue from improving residual and low level radiation protection of vehicles. For a given mission duration with an accompanying total dose limit, personnel will be denied less area due to high radiation levels. Alternatively, the stay time can be extended within a given area of responsibility. Such benefits can make the difference between mission completion and the need to withdraw. Further, they support the basic principle of keeping radiation dose to vehicle occupants as low as reasonably achievable.

1.2.4 Significant operational benefits can also accrue from improving initial radiation protection of vehicles. Increasing tank protection by a factor of 2 over existing protection will reduce vulnerability areas in the battle space by 25 percent against 10 kilo-ton (kT) weapons. For 1 kT threat weapons, this vulnerability reduction is even greater (40 percent). Wargaming in a variety of scenarios shows similar increases in crew survivability in tanks receiving radiation, with resulting increases in unit combat effectiveness. Although specifics depend on the individual

APPENDIX A. EXTRACTS AND INFORMATION FROM ALLIED ENGINEERING PUBLICATION (AEP)-14.

vehicles, it has been demonstrated for tanks that two-fold increases in neutron protection can be achieved for approximately 1 percent increases in vehicle weight. In addition, techniques for increasing neutron protection can provide substantial reductions in ballistic threat vulnerability as well. In designing a new vehicle, adopting such a combined effects approach is the most cost-effective way to optimize protection.

1.2.5 Although there are several approaches for establishing goals for crew protection, this document does not attempt to standardize such a goal. By following the guidelines herein; however, vehicle designers can substantially improve nuclear radiation protection regardless of whether or not a specific goal or requirement exists to do so, often with little cost and weight penalty and with increased ballistic survivability as well.

1.7 TEST AND EVALUATION (CHAPTER 7).

1.7.6 The primary reference used to simulate residual radiation is the radiation field produced by fission products distributed uniformly over a flat plane of 1000 m radius. The primary reference used to simulate low level radiation contamination is the radiation field produced by Cobalt-60 distributed uniformly over a flat plane of 100 m radius.

2.3 RADIATION PROTECTION FACTORS.

2.3.1 It is not possible to construct a perfect radiation shield (i.e. one where there is no penetrating radiation). By increasing a shield's thickness, a lower fraction of the incident radiation will be transmitted; however, only with an infinitely thick shield may this fraction be reduced entirely to zero. The ability of a particular shield to protect against incident radiation thus depends on its thickness, material composition, and on the type and energy of incident radiation(s). The measure (or figure of merit) of radiation shielding is commonly called the "protection factor" and defined as:

$$\textit{Protection Factor (PF)} = \frac{\textit{Free}-\textit{field radiation dose}}{\textit{Dose due to radiation penetrating the shield}} = \frac{D_o}{D_t}$$

The "free-field" radiation dose is the dose due to radiation with no shield present. Note that protection factors can also be expressed as ratios of dose rates instead of doses.

APPENDIX A. EXTRACTS AND INFORMATION FROM ALLIED ENGINEERING PUBLICATION (AEP)-14.

2.3.2 The above definition can be simply extended to the irradiation of armored vehicles. In that case, the free-field dose becomes the dose to an unprotected person with no vehicle (for penetrating radiation, the dose is determined at a reference height of 1 m above the ground). The denominator in the equation becomes the dose at some specified location inside the vehicle in question (so the PF varies with position inside the vehicle). The protection factor is thus the factor by which an individual's dose is reduced by being inside the vehicle. The higher the PF, the lower the vulnerability of a vehicle crew to radiation.

GUIDELINE 3-36. Gamma radiation in a fallout field comes mainly from the sides and from below. Protection factors of vehicles are therefore governed by shielding provided by the sides and bottom.

5.4 TOTAL DOSE IONIZATION EFFECTS ON ELECTRONICS EQUIPMENT.

5.4.5 Measured initial gamma-ray protection factors are listed in Table A-1 for various locations in selected vehicles. Light armored vehicles offer little protection and the overall dose distribution is uniform within the vehicle. Little is gained by selective placement of subsystems within these vehicles. In medium tanks, an increase of a factor of three or four is feasible by relocating equipment, for example, from the turret to a more protected position within the vehicle.

TABLE A-1. MEASURED INITIAL GAMMA-RAY PROTECTION FACTORS

VEHICLE	**DRIVER**	**TURRET (COMMANDER)**	**SQUAD**
M113A1	2.7	-	2.3
M2/M3	2.7	2.6	2.3
M1	32	6	-
LEOPARD	23	6	-
M60A1	28	7	-

5.5 LOCATIONS FOR RADIAC SENSORS.

5.5.1 One or more RADIAC sensors may be installed on a vehicle platform to measure the radiation hazard to which the crew is exposed, and to determine the external radiation hazard.

APPENDIX A. EXTRACTS AND INFORMATION FROM ALLIED ENGINEERING PUBLICATION (AEP)-14.

5.5.2 Radiation hazards to the crew may arise from external penetrating radiation, either from the surrounding environment or from contamination deposited on vehicle surfaces or within filter systems. In addition, the crew may be exposed to radioactive contamination, especially in vehicles that do not provide a collective protection (COLPRO) environment.

5.5.3 To monitor radiation exposure of the crew, a RADIAC sensor may be sited at any convenient location within the crew compartment of the vehicle. The radiation dose-rate to each crew member from widespread ground contamination may be inferred from the response of the RADIAC sensor, provided that the vehicle has been assessed for the relative variation in shielding between the crew locations and the sensor location.

5.5.4 In many scenarios involving exposure to radioactive contamination from industrial or medical sources, widespread ground contamination will not be present. Instead, local contamination or point sources of radiation will be more likely. In such cases, errors in the assessment of crew exposure could be experienced if a single fixed sensor is used. The most reliable method of monitoring crew radiation exposure is by personal RADIAC sensors closely associated with each crew member.

5.5.5 Consideration should also be given to locating RADIAC sensors close to components of the vehicle that may be expected to accumulate radioactive contamination. Such components include nuclear, biological, chemical (NBC) filtration systems and engine air filters. Vehicles that provide a COLPRO environment should also be provided with RADIAC sensors to detect ingress of radioactive contamination into the crew compartment, especially alpha and beta active materials that present a severe respiratory hazard to the crew.

5.5.6 Two approaches can be adopted in placing RADIAC sensors in vehicles to measure external free-field dose-rates:

a. Inside the vehicle.

b. Outside the vehicle.

5.5.7 If the sensor is mounted inside the vehicle, residual radiation will be scattered and attenuated by the vehicle structure and thus the sensor will not reflect the true free-field dose-rate. Therefore, a correlation factor, allowing for the effect of the vehicle must be determined. This correlation factor is the same as the acronym gamma protection factor (GPF) for that sensor position.

APPENDIX B. ACRONYMS.

µrad	micro-rad
AEP	Allied Engineering Publication
AFV	armored fighting vehicle
AR	Army Regulation
ASCII	American Standard Code for Information Interchange
COLPRO	collective protection
DoDI	Department of Defense Instruction
DTC	US Army Developmental Test Command
GRF	Gamma Range Facility
GPF	gamma protection factor
hr	hour
keV	kilo-electron volts
kT	kilo-ton
m	meter
MeV	million electron volts
MSDS	material safety data sheet
NBC	nuclear, biological, chemical
PAM	Pamphlet
PF	protection factor
rad	radiation absorbed dose
RADIAC	Radioactivity, Detection, Indication, and Computation
RDW	radiological dispersal weapons
SVAD	Survivability Vulnerability and Assessment Directorate
TOP	Test Operations Procedure
WMSR	White Sands Missile Range
WSTC	White Sands Test Center

APPENDIX C. REFERENCES.

1. DTC PAM 73-1, Developmental Test Guide, US Army Developmental Test Command, 30 October 2006.

2. AEP-14 Edition 4, Subject: Guidelines To Improve Nuclear Radiation Protection Of Military Vehicles, 1 March 2004.

For information only (related publications).

a. Army Regulation (AR) 70-75, Research, Development, and Acquisition; Survivability of Army Personnel and Materiel, 2 May 2005.

b. Department of Defense Instruction (DoDI) 5000.2, Defense Acquisition Management Policies and Procedures, 23 Oct 2000.

Forward comments, recommended changes, or any pertinent data which may be of use in improving this publication to the following address: Test Business Management Division (TEDT-TMB), US Army Developmental Test Command, 314 Longs Corner Road Aberdeen Proving Ground, MD 21005-5055. Technical information may be obtained from the preparing activity: US Army White Sands Missile Range, TEDT-WSV, White Sands Missile Range, NM 88002-5178. Additional copies can be requested through the following website: http://itops.dtc.army.mil/RequestForDocuments.aspx, or through the Defense Technical Information Center, 8725 John J. Kingman Rd., STE 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.