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INITIAL NUCLEAR RADIATION ENVIRONMENTS DUE TO TACTICAL NUCLEAR --ETC(U)

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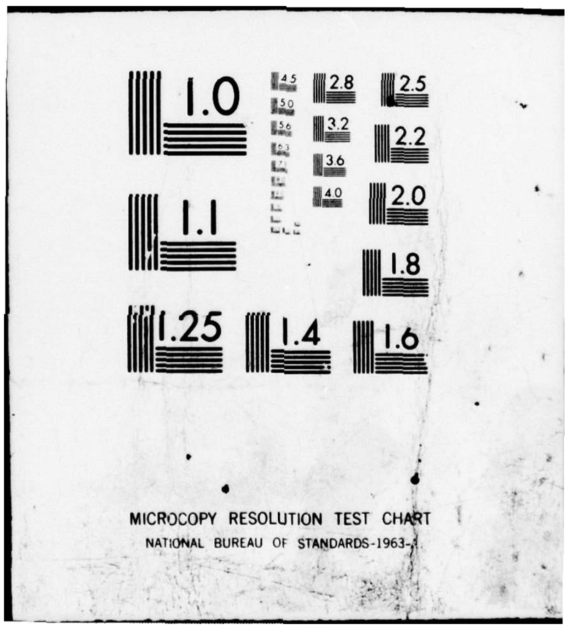
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DREO REPORT NO. [illegible]

INITIAL NUCLEAR RADIATION ENVIRONMENTS DUE TO TACTICAL NUCLEAR WEAPONS DETONATED IN AIR-OVER-GROUND AND AIR-OVER-SEA GEOMETRIES

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REPORT NO. 808

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INITIAL NUCLEAR RADIATION ENVIRONMENTS DUE TO TACTICAL NUCLEAR WEAPONS DETONATED IN AIR-OVER-GROUND AND AIR-OVER-SEA GEOMETRIES

by

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Nuclear Effects Section
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ABSTRACT

Calculations of the free-field neutron and secondary gamma-ray environments generated by the detonation of tactical standard-fission-weapons have been made for air-over-ground and air-over-seawater geometries. These data have been combined with previously published calculations of the radiation environments due to the primary prompt gamma-ray component, in order to predict the total radiation intensities induced along the air-ground interface, for various heights of weapon burst.

RÉSUMÉ

Des calculs portant sur des environnements de neutrons et de rayons-gamma secondaires générés par l'explosion d'armes nucléaires classiques à fission ont été faits pour des géométries air-sol et air-mer. Les résultats ont été ajoutés à ceux déjà publiés sur les environnements de rayonnements dus à la composante de rayonnement gamma initiale, afin de prévoir les intensités globales de rayonnement induites le long de l'interface air-sol, en fonction de l'altitude d'explosion des armes.

CONTENTS

ILLUSTRATIONS

TABLES

I INTRODUCTION

Concomitant with the greatly increased accuracy of modern missile and artillery guidance systems, there has been a reduction in nuclear weapon yield necessary to assure destruction of tactical point targets. As an example, consider a target which is moderately damaged by a blast wave of 10 psi peak overpressure. Assuming a delivery system characterized by a circular-error-probable (CEP) of one kilometre, a weapon yield of 12 kilotons would be required to ensure a 50% kill probability (1). Reduction of this CEP by a factor of two (i.e. to 500 metres), would result in the choice of a 1.4 kiloton weapon yield for the same damage probability. Thus, a reduction in necessary weapon yield by almost a factor of ten is achieved by only a two-fold reduction in guidance error.

As weapon yield is reduced, the relative importance of the three main effects (blast wave, thermal radiation, and nuclear radiation) changes drastically. This occurs as a result of the differing rates of attenuation of these effects with range from gound zero. Nuclear radiation tends to decrease in intensity much more rapidly with increasing ground range than do the other two effects. Consequently, as weapon yield (and lethal range) is reduced, the effects of initial nuclear radiation become increasingly more hazardous. For instance, doubling the range from one-half to one kilometre from a one-kiloton detonation reduces the radiation dose by a factor of 40, but the blast peak-overpressure by only a factor of 2.7. Similarly, as a weapon's yield is reduced, it may be approached more closely; consequently the radiation effects are expected to increase relatively more in severity than those due to the blast wave or thermal radiation. Continuing with the earlier example, the 12-kiloton weapon induces a radiation dose of approximately 2000 rads at the CEP boundary, whereas the more accurately guided 1.4-kiloton weapon induces a significantly higher dose of 10,000 rads at its CEP boundary. Thus, it is seen that as guidance accuracy increases, radiation hazards become of greater significance in determining casualty distributions due to tactical nuclear weapon detonations. It is estimated that for standard-fission-weapons of yield less than eight kilotons, radiation injury (immediate transient incapacitation) will be the dominant mode of personnel lethality (2).

A further consequence is apparent when the vulnerability of armoured vehicle crews is considered. Heavily armoured vehicles have in the past been designed to provide protection against conventional weaponry, and as such are also inherently resistant to the blast and thermal effects of nuclear weapons. Typical tank armour, however, provides substantially less protection against initial nuclear radiation, especially the fast-neutron component. Consequently, the shift to smaller, more accurately delivered nuclear munitions implies their even greater usefulness in the anti-armour role, due to the more intense and more penetrating nuclear radiation component.

As an aid to the further consideration of such consequences, a series of representative calculations of expected radiation dose distributions were made for representative standard-fission-weapon detonations. Two geometries were considered; air-over-ground and air-over-seawater. In each case, calculations were made for four heights-of-burst, namely 1, 250, 500, and 750 metres. Only one weapon yield was considered (one kiloton), however linear scaling of the radiation intensities quoted may be made up to a yield of ten kilotons, where non-linearities in the primary gamma-ray component due to cloud-rise and hydrodynamic enhancement may become significant (3).

II NUMERICAL METHODS

Neutron and Secondary Gamma-ray Calculations

Neutron transport calculations were made using the DOT-III (4) two-dimensional discrete-ordinates radiation transport code. Concurrent with the calculation of primary neutron transport, calculations were also performed for the generation and transport of secondary gamma-rays, arising from radiative capture of neutrons by the nuclei of the transport media. The spatial mesh chosen consisted of 15 radial cells, ranging from 0 to 1600 metres; and 25 axial cells, 10 of which extended to a depth of 1.65 metres below the air/surface interface, and 15 of which extended vertically to an altitude of 1600 metres. Angular integration was performed using an S-6 quadrature consisting of 30 discrete directions. Anisotropy of the neutron scattering and gamma-ray production cross-sections was considered up to the third order of a Legendre expansion, i.e. the P-3 approximation. Variation of particle energy was accounted for by a 58-group structure, consisting of 37 neutron energy groups and 21 gamma-ray energy groups.

Primary Gamma-ray Calculations

The transport of primary weapon gamma-rays was not calculated in this study. Instead, the previously published data of French and Mooney (3) was adopted, primarily because their model considered such time-dependant effects as cloud-rise and hydrodynamic enhancement during the initial decay of weapon fission-products, which are beyond the capabilities of the DOT-III code. Such time-dependant effects are of importance only to the primary gamma-ray component, as gamma-rays are continuously emitted for some time after detonation, during the vertical rise of the fireball. Neutrons, on the other hand, are emitted almost entirely during the very early stages of the explosion, travelling in undisturbed air, in advance of both the shock front and thermal radiation.

III NUCLEAR INTERACTION DATA

Nuclear Cross-Section Data

Nuclear interaction data required for these calculations were obtained from the latest version (Oct 1977) of the DLC-31 Defense Nuclear Agency data library (5). The library structure consisting of 37 neutron and 21 gamma-ray energy groups was adopted without modification. The densities of oxygen and nitrogen in air were chosen to correspond with the ICAO description (6) of standard atmosphere at sea-level and a temperature of 15° Celsius. The composition of the ground was determined by including the five most common elements of the earth's crust (6) plus hydrogen. Seawater was characterized similarly by including the five most common constituents (6). The compositions and densities of the three media involved are listed in Table 1.

The microscopic DLC-31 data were retrieved, scaled, and combined into the three required macroscopic data sets using a modified version of the APRFX multi-group cross-section collapsing code (7).

Neutron Source Description

The neutron source description utilized for these calculations was derived from the spectrum of Bartine, et al (5), re-normalized to a total source strength of 10^{23} neutrons per kiloton, as suggested by French and Mooney (3). The neutron source spectrum, in its DLC-31 representation, is listed in Table 2.

ELEMENT	DENSITY (atoms/barn·cm)		
	Air	Ground	Seawater
Hydrogen		2.23E-3	6.64E-2
Oxygen	1.07E-5	4.69E-2	3.32E-2
Nitrogen	4.02E-5		
Sodium		1.98E-3	2.81E-4
Magnesium			3.00E-5
Aluminium		4.84E-3	
Silicon		1.59E-2	
Chlorine			3.30E-4
Iron		1.44E-3	
DENSITY ($grams/cm^3$)	1.22E-3	2.41	1.025

Table 1 : Elemental composition and densities of representative air, ground, and seawater.

Group	Upper Energy (MeV)	Source (n/kton)
9	10.0	3.84E+20
10	9.05	3.50E+20
11	8.19	5.39E+20
12	7.41	7.35E+20
13	6.38	1.84E+21
14	4.97	3.25E+20
15	4.72	8.47E+20
16	4.07	5.50E+21
17	3.01	3.24E+21
18	2.39	1.06E+21
19	2.31	9.72E+21
20	1.83	1.47E+22
21	1.11	2.16E+22
22	0.550	1.50E+22
23	0.158	1.93E+21
24	0.111	1.21E+22
25	0.0525	5.73E+21
26	0.0248	6.00E+20
27	0.0219	2.40E+21
28	0.0103	1.44E+21
	0.0034	
Total Source :		1.00E+23

Table 2 : Low-yield standard-fission-weapon neutron source in 37 neutron group format.

Detector Response Description

To predict a single radiation intensity at each space-point, it is necessary to integrate the calculated multi-group neutron and gamma-ray spectra against the appropriate fluence-to-dose conversion functions. In order to be consistent with the current NATO definitions of radiation intensity, the chosen conversion functions consisted of the "tissue-kerma" factors supplied with the DLC-31 library (5) as listed in Tables 3a and 3b. The use of these kerma factors in the "free-in-air tissue-kerma" sense implies an assumption that the radiation energy released in a small piece of non-perturbing wet tissue is a useful indicator of probable radio-biological effect.

Group	Upper Energy (MeV)	Kerma/Fluence ($rad \cdot cm^2$)
38	1.4000E 01	3.0426E-09
39	1.0000E 01	2.4074E-09
40	8.0000E 00	2.0855E-09
41	7.0000E 00	1.8788E-09
42	6.0000E 00	1.6738E-09
43	5.0000E 00	1.4601E-09
44	4.0000E 00	1.2317E-09
45	3.0000E 00	1.0481E-09
46	2.5000E 00	9.1487E-10
47	2.0000E 00	7.6774E-10
48	1.5000E 00	5.9765E-10
49	1.0000E 00	4.3624E-10
50	7.0000E-01	3.0502E-10
51	4.5000E-01	1.9777E-10
52	3.0000E-01	1.1133E-10
53	1.5000E-01	5.5597E-11
54	1.0000E-01	4.0199E-11
55	7.0000E-02	4.0885E-11
56	4.5000E-02	7.3424E-11
57	3.0000E-02	1.6328E-10
58	2.0000E-02	5.2217E-10
	1.0000E-02	

Table 3a : DLC-31 gamma-ray fluence-to-kerma conversion factors.

Group	Upper Energy (MeV)	Kerma/Fluence (rad·cm^2)
1	1.9640E 01	6.9955E-09
2	1.6905E 01	6.6398E-09
3	1.4918E 01	6.4306E-09
4	1.4191E 01	6.3273E-09
5	1.3840E 01	6.1858E-09
6	1.2840E 01	6.0025E-09
7	1.2214E 01	5.9348E-09
8	1.1052E 01	5.6816E-09
9	1.0000E 01	5.5284E-09
10	9.0484E 00	5.2212E-09
11	8.1873E 00	5.1231E-09
12	7.4082E 00	4.8639E-09
13	6.3763E 00	4.5598E-09
14	4.9649E 00	4.3203E-09
15	4.7237E 00	4.2551E-09
16	4.0657E 00	4.0438E-09
17	3.0119E 00	3.4289E-09
18	2.3852E 00	3.1396E-09
19	2.3069E 00	3.0709E-09
20	1.8268E 00	2.6457E-09
21	1.1080E 00	2.0090E-09
22	5.5023E-01	1.2468E-09
23	1.5764E-01	7.6831E-10
24	1.1109E-01	5.3516E-10
25	5.2475E-02	3.0158E-10
26	2.4788E-02	2.0519E-10
27	2.1875E-02	1.4102E-10
28	1.0333E-02	6.0073E-11
29	3.3546E-03	2.1225E-11
30	1.2341E-03	8.8838E-12
31	5.8295E-04	3.0744E-12
32	1.0130E-04	1.1410E-12
33	2.9023E-05	1.1243E-12
34	1.0677E-05	1.6859E-12
35	3.0590E-06	2.8218E-12
36	1.1254E-06	4.5992E-12
37	4.1400E-07	1.8828E-11
	1.0000E-11	

Table 3b : DLC-31 neutron fluence-to-kerma conversion factors.

IV RESULTS

Kerma Distributions

The predictions of neutron, total gamma-ray, and total radiation free-in-air tissue-kermas, are shown plotted as functions of surface range for the eight cases considered, in Figures 5 through 10 of Appendix A. Listed in Tables 4 through 11 are the corresponding numerical values, including also a breakdown of the primary and neutron-generated secondary gamma-ray components.

Comparison to ORNL Calculations

Comparison of these results to those of other recent investigations (8,9) of the air-over-ground problem cannot be entirely definitive, as different numerical approximations, air and ground compositions, source descriptions, and detector response functions have been variously employed. A recent ORNL report (8) is reasonably consistent with this study, with the notable exception that the response functions utilized were those normally applicable to health physics problems, namely the Auxier-Snyder (10) and Claiborne-Trubey (11) tissue-equivalent phantom responses. In order to make a direct comparison with these results, the neutron and secondary gamma-ray spectra, calculated for the one-metre burst over ground, were re-folded against the above-mentioned response functions and compared to the calculations of Pace, et al.

The modified DREO and ORNL calculations of neutron and secondary gamma-ray tissue doses are shown in comparison in Figure 1. The agreement is seen to be excellent out to a ground range of about 1000 metres, where the DREO results start to exceed those of ORNL, reaching a maximum difference of about 50% near the problem boundary. It is felt that this may be due to a difference in location of the radial boundary, through which no particles are assumed to return. In the ORNL study this is located 110 metres closer than in the DREO approximation, and thus could exert a greater influence on the nearby particle fluences. The secondary gamma-ray doses also compare well, the agreement improving in this case as ground range increases. The general disagreement of about 30% is likely due to differing ground compositions and densities, the ground being the source of the majority of gamma-rays near the air/surface interface. The overall agreement of both neutron and secondary gamma-ray doses is probably as good as could be expected however, especially when it is noted that the absolute values of the quantities calculated vary over more than five decades.

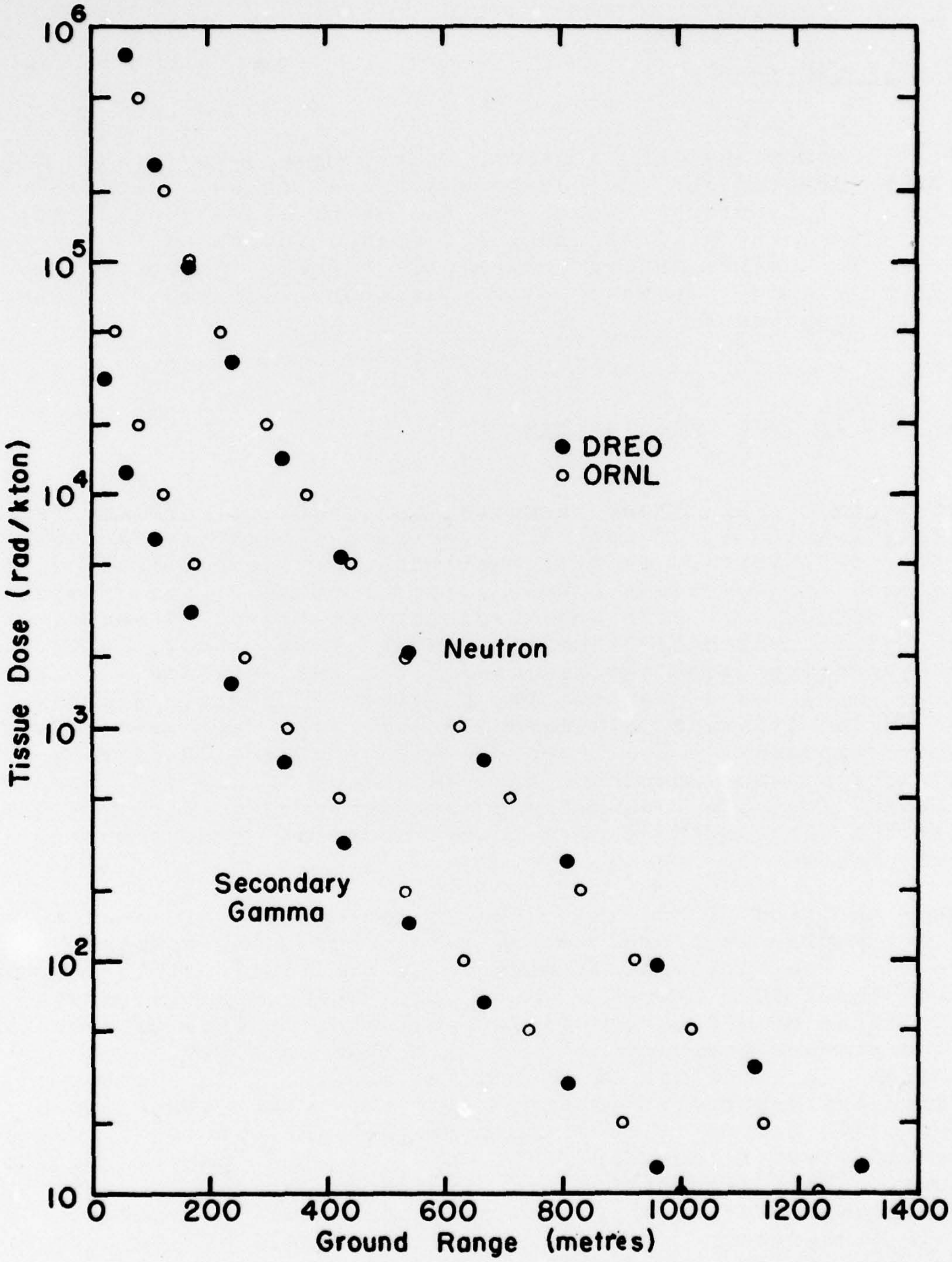

Figure 1 : Comparison of ORNL and DREO calculations of primary neutron and secondary gamma-ray doses, for a burst height of one metre.

Comparison to SAI Calculations

A comparison is also made to recent SAI (Science Applications Inc.) calculations (9), for a burst height of 250 metres over ground (actually 278 metres for SAI). In this case it is the total free-in-air tissue-kerma which is compared in Figure 2, again as a function of ground range. The agreement of the two calculations is generally very good, however in this case the DREO results tend to attenuate more rapidly with increasing ground range than do those of SAI. This is undoubtedly explained by the difference in air density used in the two reports, namely 1.11 grams/litre for SAI versus 1.22 grams/litre in the DREO study. An increase in air density will reduce the fluences at large distances due to increased absorption by the intervening air. At short ranges the opposite will occur, namely an increase in fluence is expected due to a more rapid conversion of uncollided weapon radiation into a "diffusing" state, due to an increase in scattering probability per unit distance of travel.

Comparison of Air/Sea to Air/Ground Results

In Figure 3 a comparison is made between the results of the air-over-sea and air-over-ground calculations, for the same burst height of 250 metres. The effect of changing the sub-surface composition is as expected, namely a decrease in neutron kerma coupled with an increase in total gamma-ray kerma. The decrease in neutron kerma to about 60% of the air-over-ground values is due to the much greater moderating power of the water, primarily a result of hydrogen scattering. With a decrease in average neutron energy comes an expected increase in radiative neutron-capture probability, hence an increase in gamma-ray kerma. The magnitude of the increased secondary gamma-ray contribution itself decreases with increasing surface range, due to a more rapid attenuation with distance of the originating neutron fluence. The net result of the combination of the two effects is a decrease in total radiation kerma to approximately 80% of the corresponding air-over-ground intensity.

Note that the assumption has been made that the primary gamma-ray data of French and Mooney (3) are equally applicable also to the air-over-sea conditions. This is felt to be reasonable, since primary gamma-rays contribute generally less than 25% to the total kerma, and their transport characteristics are much less dependent on the specific nuclear species of the surface than are the primary neutrons and their gamma-ray secondaries.

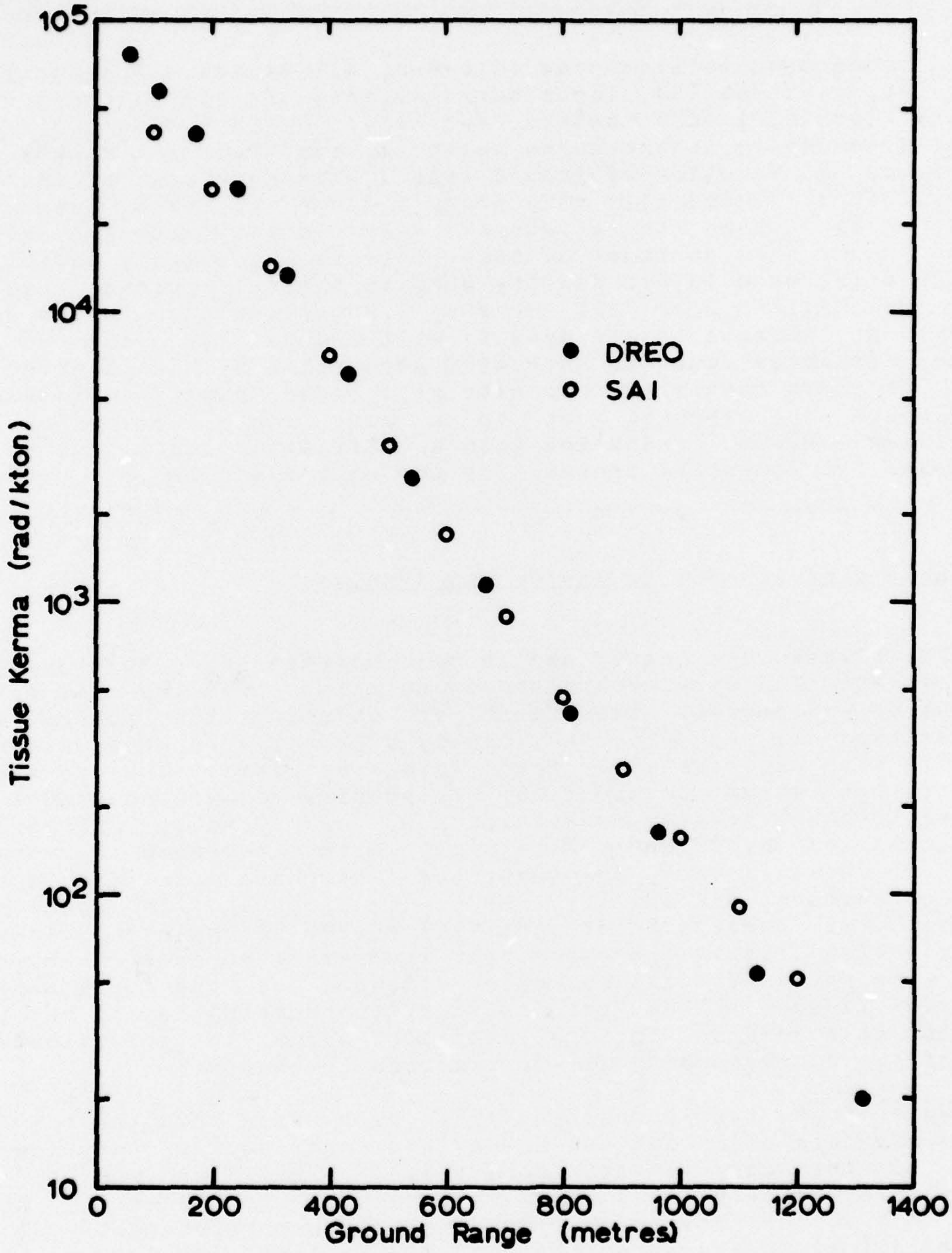

Figure 2 : Comparison of SAI and DREO calculations of total radiation kerma, for a burst height of 250 metres.

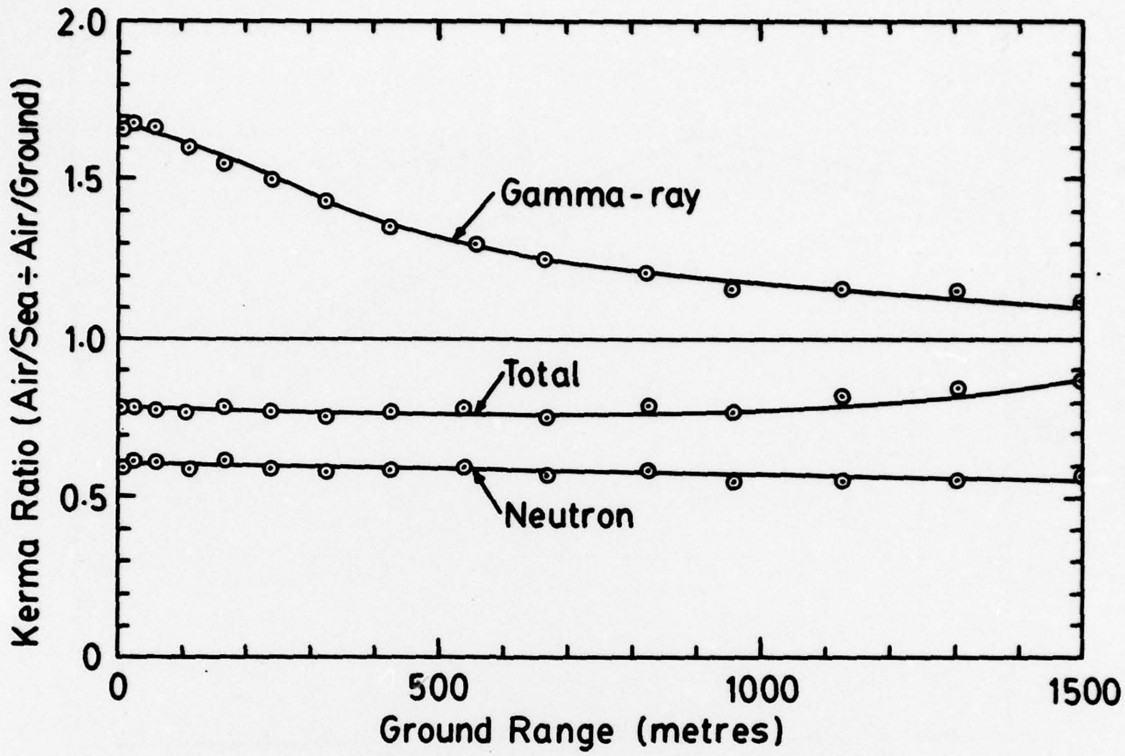

Figure 3 : Comparison of Air/Sea and Air/Ground calculations of gamma-ray, neutron, and total kermas, for a burst height of 250 metres.

Effect of Burst Height on Radiation Propogation

For the eight cases considered, the surface ranges at which total radiation kermas of 500 rads are realized were compared to height of burst, in order to investigate the effect of this parameter on weapon lethality. The data are shown in Figure 4, and demonstrate a clear optimum height of burst for the maximization of radiation intensity at long distances from surface zero. A burst height near 250 metres is seen to be optimal both for air-over-ground and air-over-sea conditions. At lower burst heights the ground (or sea) exerts an increased influence due to particle absorption and moderation, whereas at higher burst heights geometric effects dominate (i.e. increased slant range). Note that optimal burst heights corresponding to criteria other than 500 rads will in general be different from 250 metres, but may be extracted from the data of Appendix A if required.

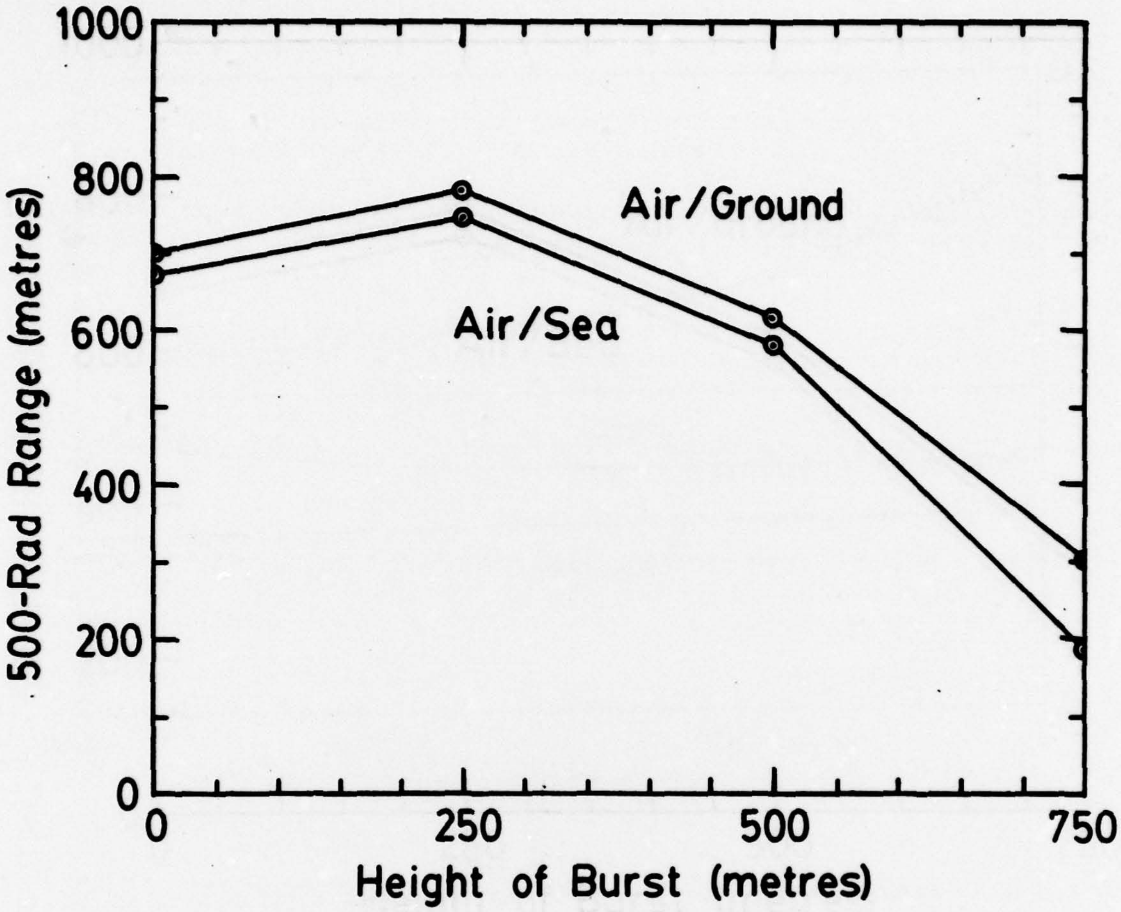

Figure 4 : Effect of weapon burst height on range of total radiation kerma.

V CONCLUSIONS

Nuclear radiation environments have been predicted for representative tactical nuclear detonations applicable to land and naval forces. The calculations were made using the most recent Defense Nuclear Agency (US) nuclear interaction data compilations and are estimated to be accurate to within ± 30%. The predictions were verified to be consistent with those of two other research laboratories, inasmuch as the underlying assumptions were not always identical. The effects of burst height on weapon radiation lethality were investigated, and the expected differences between land and naval environments determined.

VI REFERENCES

1. "The Effects of Nuclear Weapons"; S.Glasstone and P.J.Dolan; U.S. Government Printing Office, (1977)

2. "The Army Nuclear Survivability Program"; Nuclear Notes Number 2; U.S. Army Nuclear and Chemical Agency, Fort Belvoir, (Oct 1974)

3. "Initial Radiation Exposure From Nuclear Weapons";R.L.French and L.G.Mooney; Radiation Research Laboratories, RRA-T7201, (July 1972)

4. "The DOT-III Two Dimensional Discrete Ordinates Transport Code"; F.R.Mynatt, _et al_; Oak Ridge National Laboratory, ORNL-TM-4280, (June 1973)

5. "Production and Testing of the DNA Few Group Cross Section Library"; D.E. Bartine, _et al_; Oak Ridge National Laboratory, ORNL-TM-4840, (Oct 1975)

6. "Handbook of Chemistry and Physics"; The Chemical Rubber Company; 49 _th_ Edition, (1969)

7. "Neutron Cross-Section Collapsing Code - APRFX-I"; P.S. Pickard; Ballistics Research Laboratory, AMXRD-BRL (12-70), (June 1970)

8. "Neutron and Secondary-Gamma-Ray Transport Calculations for 14 MeV and Fission Neutron Sources in Air-over-Ground and Air-over-Seawater Geometries"; J.V.Pace III, _et al_; Oak Ridge National Laboratory, ORNL-TM-4841, (Aug 1975)

9. "Radiation Environments from Tactical Nuclear Weapons"; M.Gritzner, _et al_; Science Applications Inc., DNA-4267F, (July 1976)

10. "Protection Against Neutron Radiation"; National Council on Radiation Protection and Measurements; Washington, D.C., NCRP-38, (1971)

11. "Dose Rates in a Slab Phantom from Monoenergetic Gamma-Rays"; H.C.Claiborne and D.K.Trubey; Nucl. Appl. Tech. _8_,450 (1970)

VII APPENDIX A

The following pages contain plots of the calculated neutron, gamma-ray, and total kerma distributions along the air/surface interface (Figures 5 through 10); and listings of the corresponding neutron, secondary gamma-ray, primary gamma-ray, total gamma-ray, and total radiation kerma distributions (Tables 4 through 11).

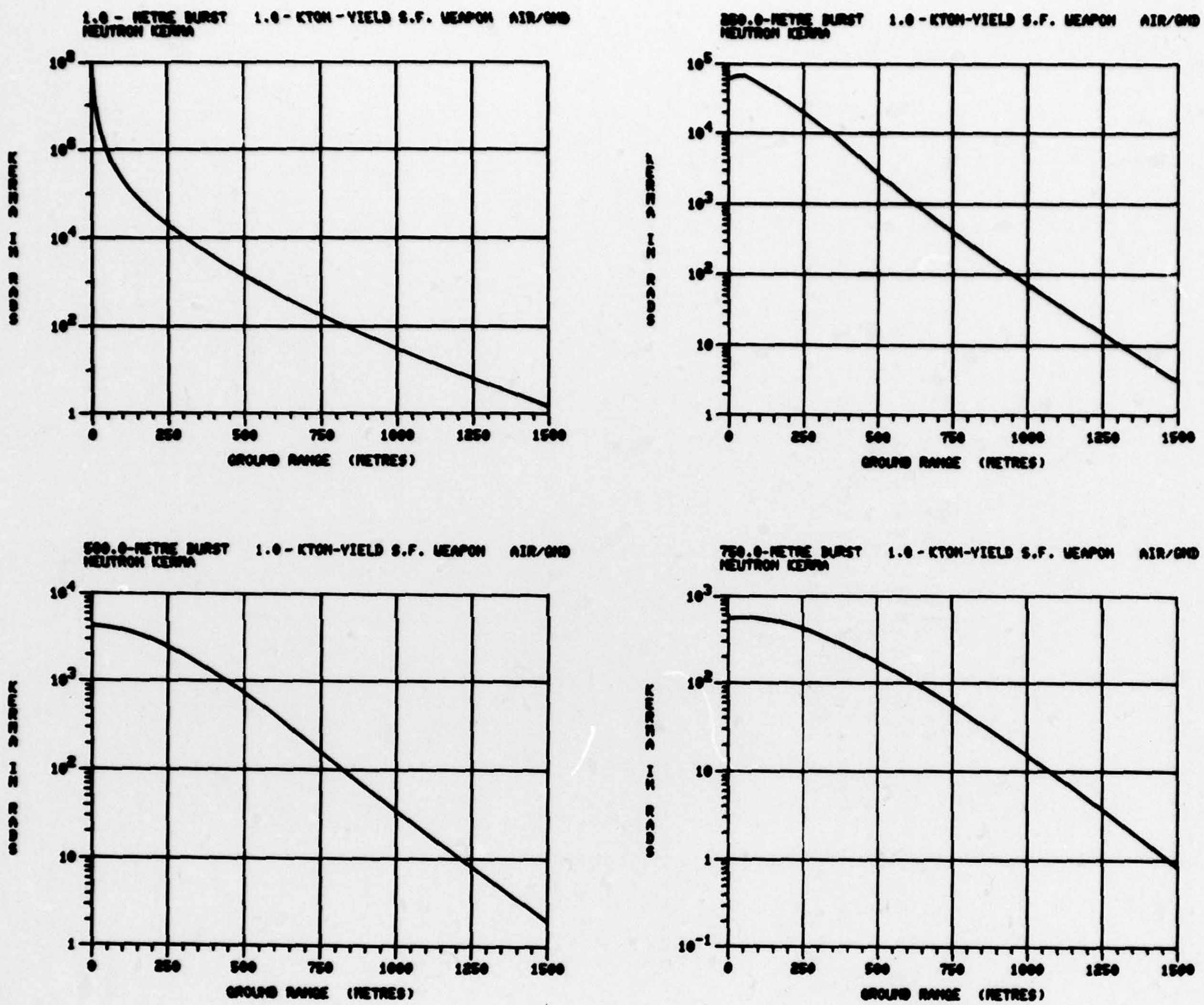

Figure 5 : Neutron kerma distributions in air-over-ground geometries.

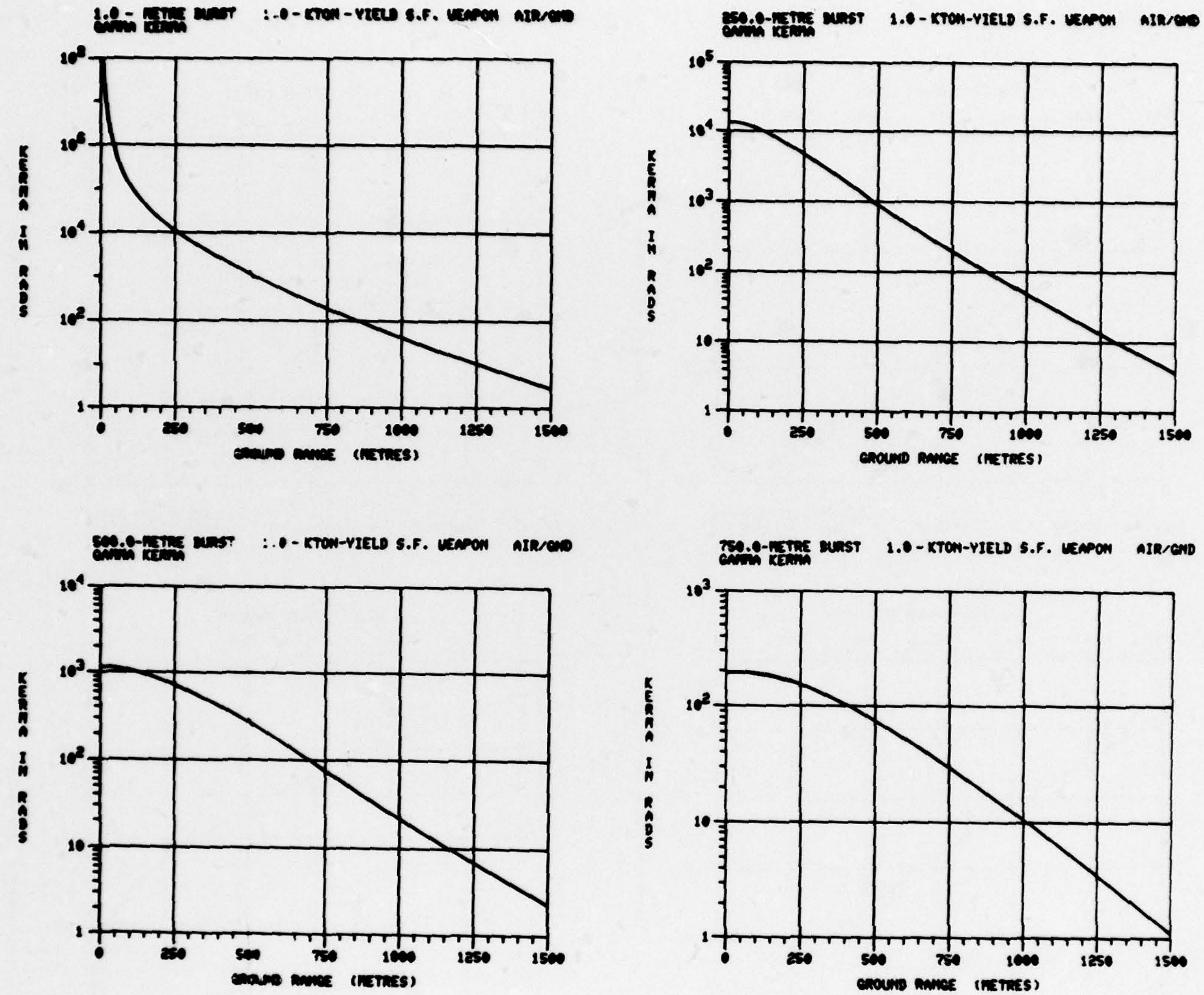

Figure 6 : Gamma-ray kerma distributions in air-over-ground geometries.

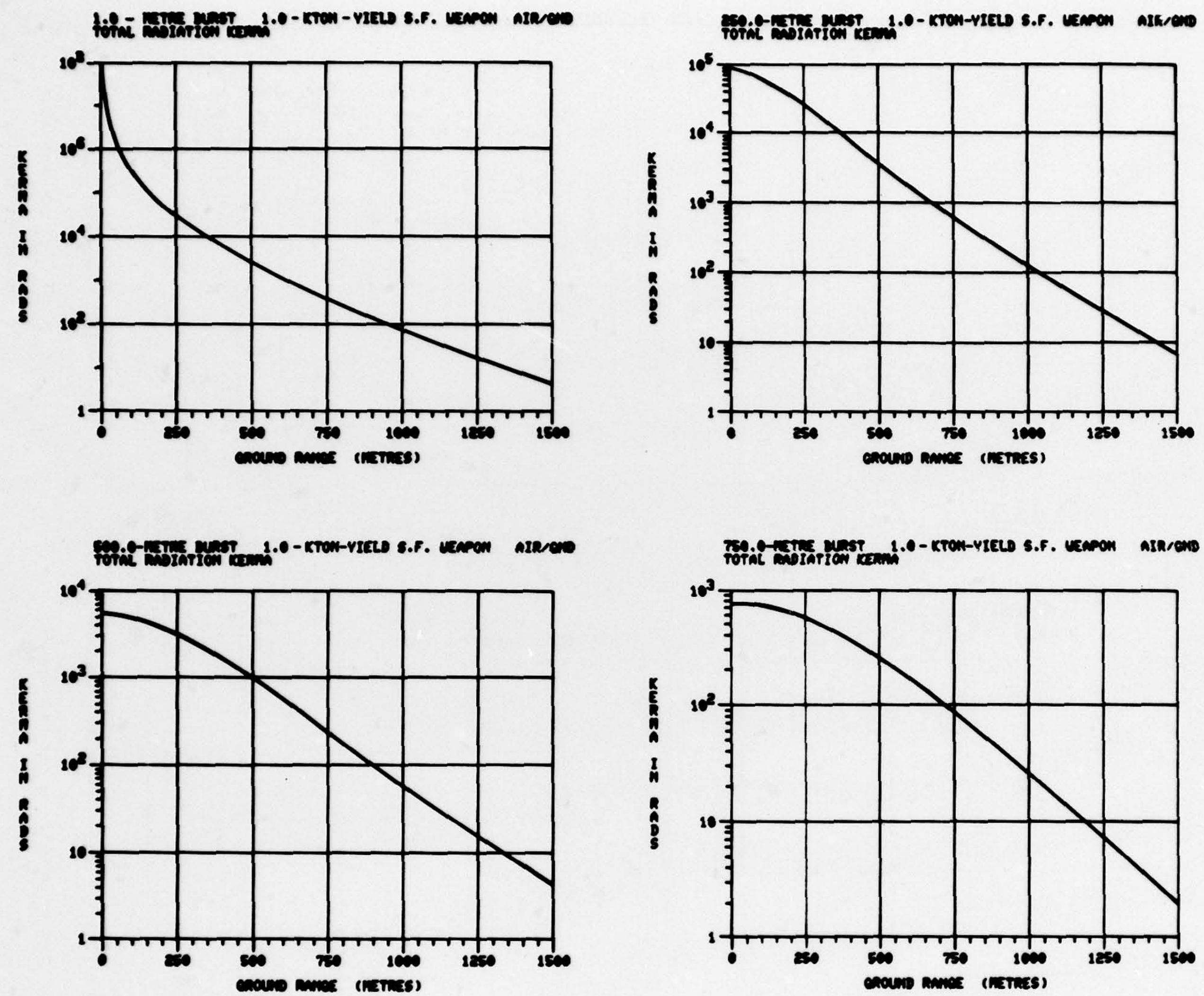

Figure 7 : Total radiation kerma distributions in air-over-ground geometries.

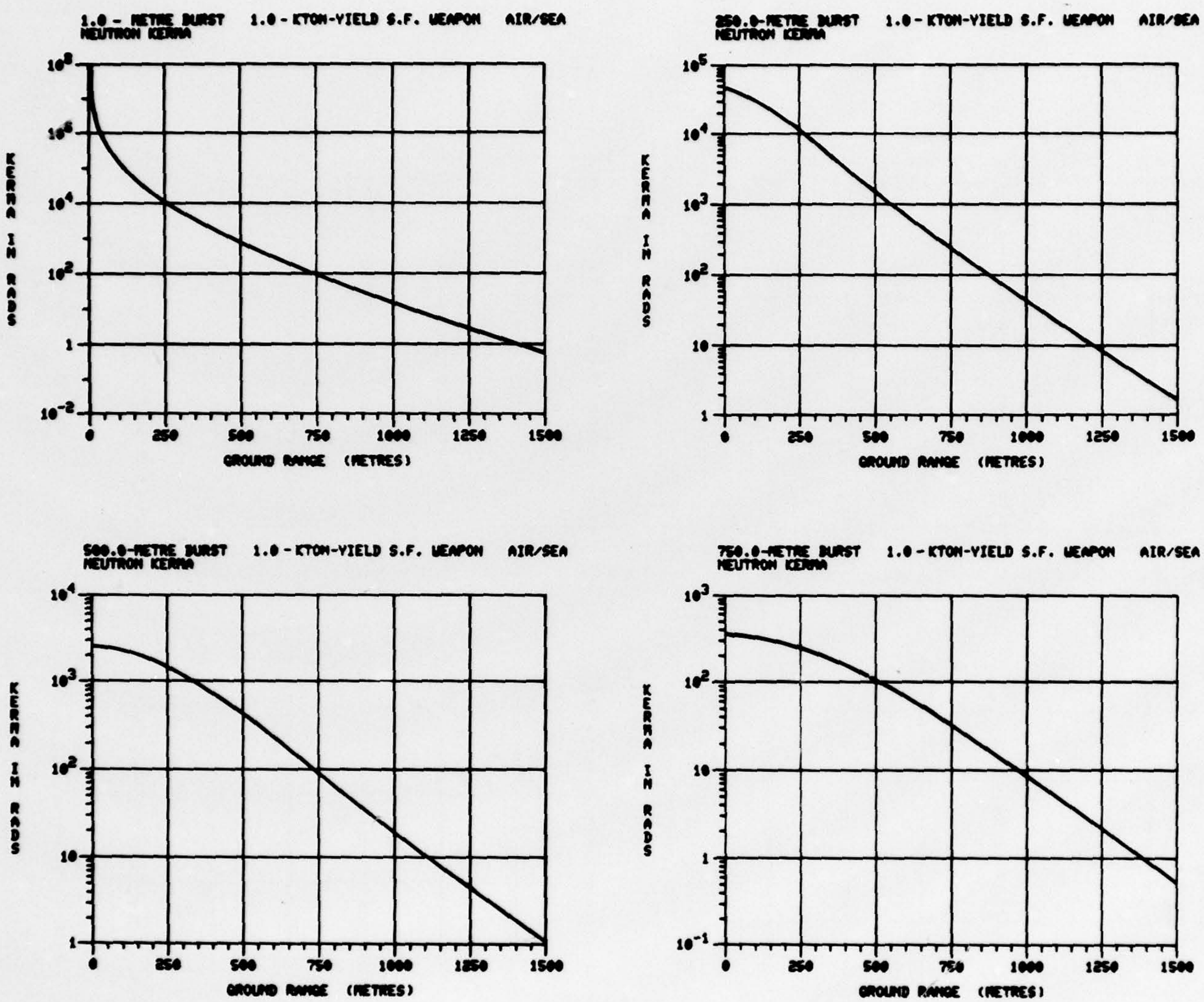

Figure 8 : Neutron kerma distributions in air-over-sea geometries.

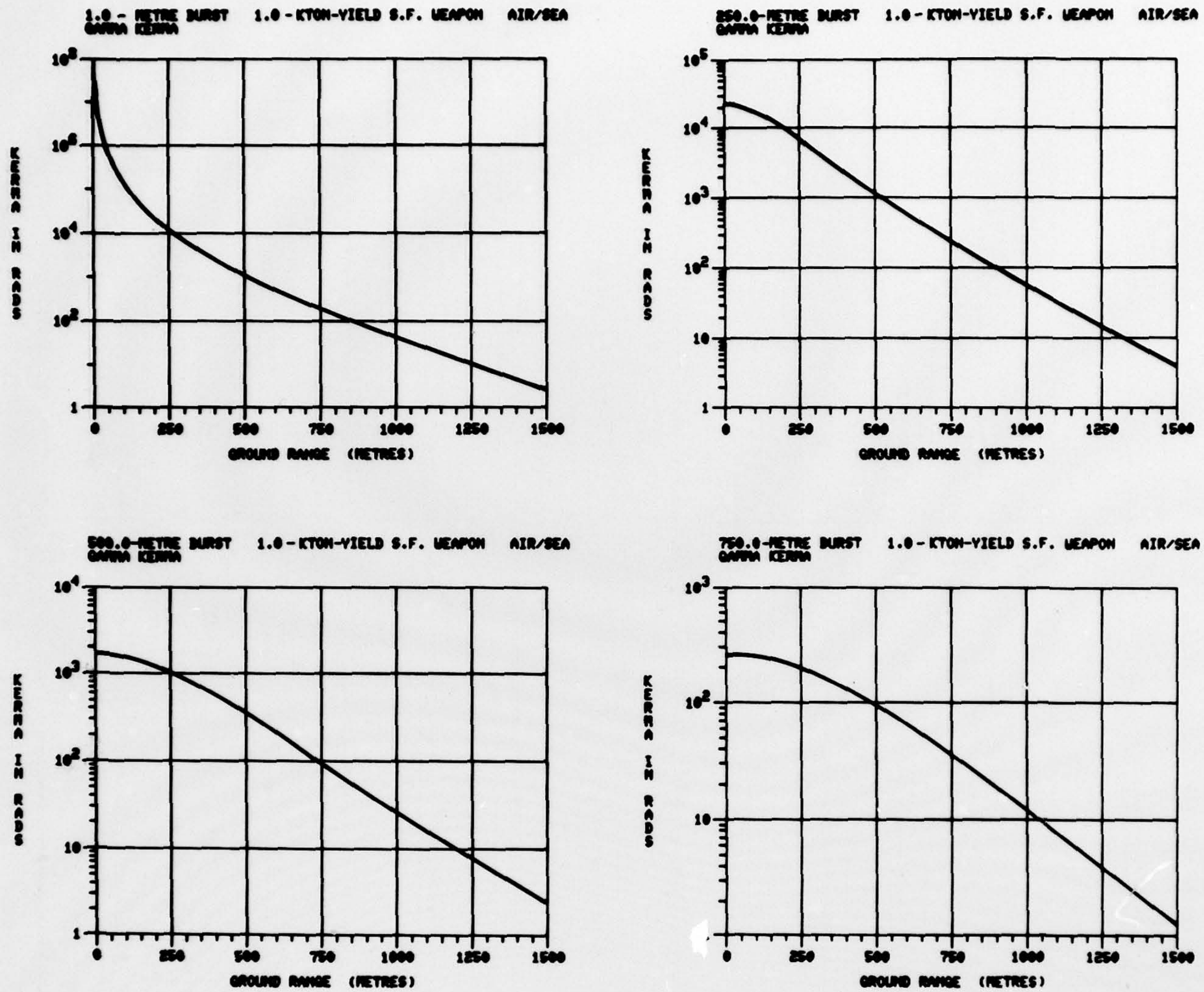

Figure 9 : Gamma-ray kerma distributions in air-over-sea geometries.

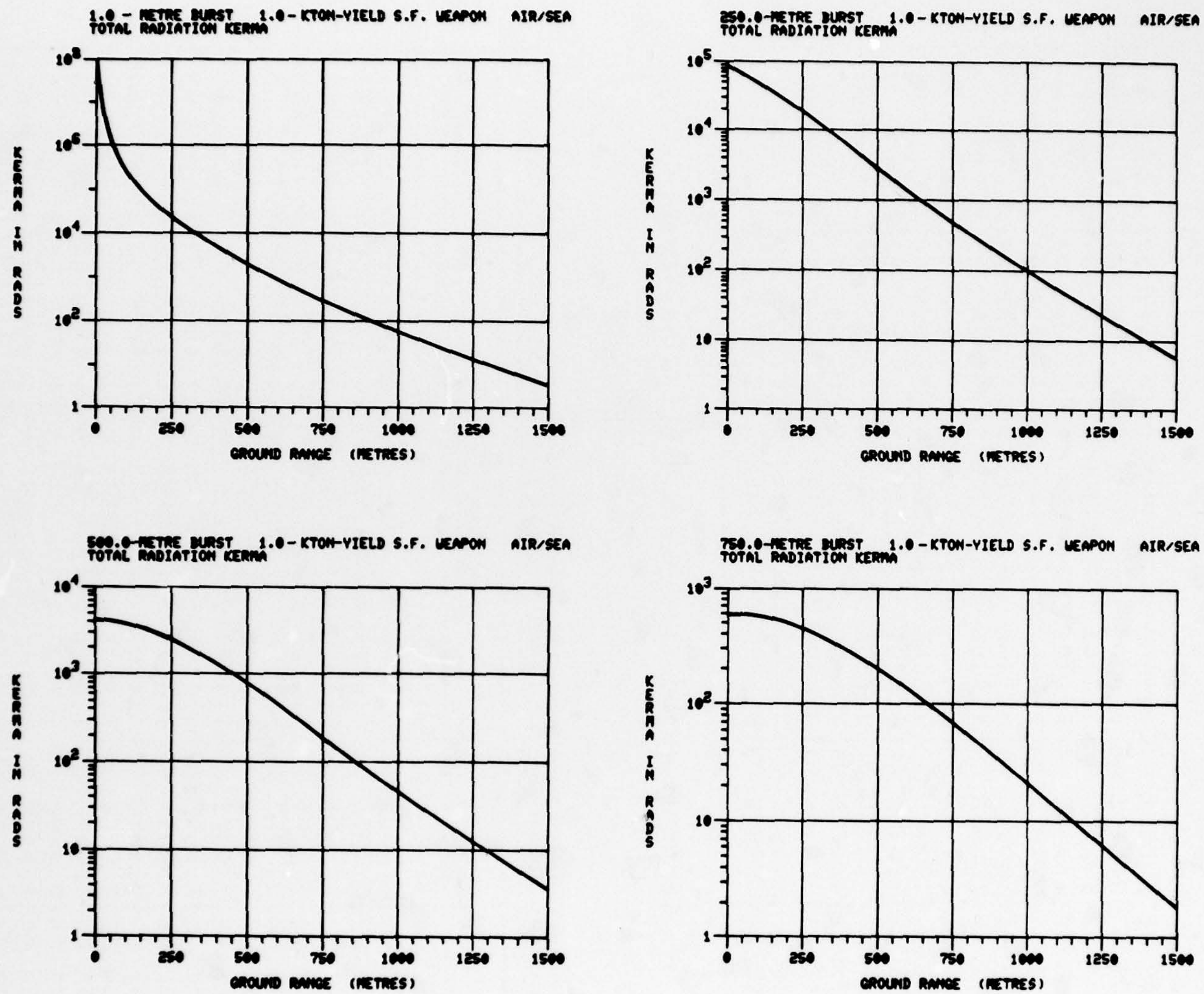

Figure 10 : Total radiation kerma distributions in air-over-sea geometries.

1-METRE BURST OVER GROUND		1-KTON STANDARD-FISSION-WEAPON			
RANGE (METRES)	KERMA (RADS)				
	NEUTRON	SEC GAMMA	PRI GAMMA	TOT GAMMA	TOT KERMA
7.000E 00	2.050E 07	8.980E 04	2.955E 07	2.964E 07	5.014E 07
2.700E 01	2.610E 06	2.920E 04	1.873E 06	1.902E 06	4.512E 06
6.000E 01	5.210E 05	1.150E 04	3.339E 05	3.454E 05	8.664E 05
1.070E 02	1.630E 05	5.920E 03	8.746E 04	9.338E 04	2.564E 05
1.670E 02	5.580E 04	2.860E 03	2.843E 04	3.129E 04	8.709E 04
2.400E 02	2.090E 04	1.400E 03	1.036E 04	1.176E 04	3.266E 04
3.270E 02	7.630E 03	6.470E 02	3.977E 03	4.624E 03	1.225E 04
4.270E 02	2.750E 03	2.940E 02	1.580E 03	1.874E 03	4.624E 03
5.400E 02	1.030E 03	1.350E 02	6.365E 02	7.715E 02	1.801E 03
6.670E 02	3.230E 02	6.130E 01	2.545E 02	3.158E 02	6.388E 02
8.070E 02	1.190E 02	2.730E 01	1.008E 02	1.281E 02	2.471E 02
9.600E 02	4.020E 01	1.190E 01	3.926E 01	5.116E 01	9.136E 01
1.127E 03	1.310E 01	5.250E 00	1.487E 01	2.012E 01	3.322E 01
1.307E 03	4.590E 00	2.160E 00	5.486E 00	7.646E 00	1.224E 01
1.500E 03	1.350E 00	8.330E-01	1.965E 00	2.798E 00	4.148E 00

Table 4 : Kerma distributions for a 1-metre burst over ground.

250-METRE BURST OVER GROUND		1-KTON STANDARD-FISSION WEAPON			
RANGE (METRES)	KERMA (RADS)				
	NEUTRON	SEC GAMMA	PRI GAMMA	TOT GAMMA	TOT KERMA
7.000E 00	6.040E 04	4.920E 03	8.239E 03	1.316E 04	7.356E 04
2.700E 01	6.850E 04	4.980E 03	8.108E 03	1.309E 04	8.159E 04
6.000E 01	6.450E 04	4.730E 03	7.587E 03	1.232E 04	7.682E 04
1.070E 02	4.840E 04	4.000E 03	6.401E 03	1.040E 04	5.880E 04
1.670E 02	3.360E 04	2.990E 03	4.683E 03	7.673E 03	4.127E 04
2.400E 02	2.180E 04	2.060E 03	2.948E 03	5.008E 03	2.681E 04
3.270E 02	1.090E 04	1.190E 03	1.622E 03	2.812E 03	1.371E 04
4.270E 02	4.650E 03	6.120E 02	8.119E 02	1.424E 03	6.074E 03
5.400E 02	1.990E 03	3.030E 02	3.800E 02	6.830E 02	2.673E 03
6.670E 02	8.310E 02	1.420E 02	1.680E 02	3.100E 02	1.141E 03
8.070E 02	2.720E 02	6.350E 01	7.129E 01	1.348E 02	4.068E 02
9.600E 02	1.040E 02	2.830E 01	2.916E 01	5.746E 01	1.615E 02
1.127E 03	2.970E 01	1.220E 01	1.144E 01	2.364E 01	5.334E 01
1.307E 03	1.020E 01	5.270E 00	4.335E 00	9.605E 00	1.981E 01
1.500E 03	2.950E 00	2.080E 00	1.584E 00	3.664E 00	6.614E 00

Table 5 : Kerma distributions for a 250-metre burst over ground.

500-METRE BURST OVER GROUND			1-KTON STANDARD-FISSION-WEAPON		
RANGE (METRES)	KERMA (RADS)				
	NEUTRON	SEC GAMMA	PRI GAMMA	TOT GAMMA	TOT KERMA
7.000E 00	4.290E 03	4.260E 02	6.928E 02	1.119E 03	5.409E 03
2.700E 01	4.040E 03	4.230E 02	6.891E 02	1.112E 03	5.152E 03
6.000E 01	3.930E 03	4.140E 02	6.738E 02	1.088E 03	5.018E 03
1.070E 02	3.700E 03	3.940E 02	6.341E 02	1.028E 03	4.728E 03
1.670E 02	3.300E 03	3.590E 02	5.610E 02	9.200E 02	4.220E 03
2.400E 02	2.620E 03	3.000E 02	4.554E 02	7.554E 02	3.375E 03
3.270E 02	1.740E 03	2.190E 02	3.322E 02	5.512E 02	2.291E 03
4.270E 02	1.030E 03	1.480E 02	2.171E 02	3.651E 02	1.395E 03
5.400E 02	5.940E 02	9.260E 01	1.277E 02	2.203E 02	8.143E 02
6.670E 02	2.520E 02	4.830E 01	6.804E 01	1.163E 02	3.683E 02
8.070E 02	1.090E 02	2.370E 01	3.343E 01	5.713E 01	1.661E 02
9.600E 02	4.150E 01	1.110E 01	1.532E 01	2.642E 01	6.792E 01
1.127E 03	1.550E 01	5.320E 00	6.572E 00	1.189E 01	2.739E 01
1.307E 03	5.820E 00	2.710E 00	2.669E 00	5.379E 00	1.120E 01
1.500E 03	1.730E 00	1.210E 00	1.030E 00	2.240E 00	3.970E 00

Table 6 : Kerma distributions for a 500-metre burst over ground.

750-METRE BURST OVER GROUND			1-KTON STANDARD-FISSION-WEAPON		
RANGE (METRES)	KERMA (RADS)				
	NEUTRON	SEC GAMMA	PRI GAMMA	TOT GAMMA	TOT KERMA
7.000E 00	5.500E 02	8.260E 01	1.079E 02	1.905E 02	7.405E 02
2.700E 01	5.570E 02	8.260E 01	1.076E 02	1.902E 02	7.472E 02
6.000E 01	5.520E 02	8.160E 01	1.062E 02	1.878E 02	7.398E 02
1.070E 02	5.230E 02	7.860E 01	1.027E 02	1.813E 02	7.043E 02
1.670E 02	4.820E 02	7.440E 01	9.573E 01	1.701E 02	6.521E 02
2.400E 02	4.330E 02	6.760E 01	8.462E 01	1.522E 02	5.852E 02
3.270E 02	3.390E 02	5.530E 01	6.955E 01	1.248E 02	4.638E 02
4.270E 02	2.250E 02	4.110E 01	5.249E 01	9.359E 01	3.186E 02
5.400E 02	1.450E 02	2.890E 01	3.608E 01	6.498E 01	2.100E 02
6.670E 02	8.810E 01	1.900E 01	2.245E 01	4.145E 01	1.295E 02
8.070E 02	4.010E 01	1.090E 01	1.272E 01	2.362E 01	6.372E 01
9.600E 02	1.820E 01	5.490E 00	6.609E 00	1.210E 01	3.030E 01
1.127E 03	7.240E 00	2.960E 00	3.158E 00	6.118E 00	1.336E 01
1.307E 03	2.660E 00	1.300E 00	1.404E 00	2.704E 00	5.364E 00
1.500E 03	8.410E-01	5.600E-01	5.846E-01	1.145E 00	1.986E 00

Table 7 : Kerma distributions for a 750-metre burst over ground.

1-METRE BURST OVER SEA			1-KTON STANDARD-FISSION-WEAPON		
RANGE (METRES)	KERMA (RADS)				
	NEUTRON	SEC GAMMA	PRI GAMMA	TOT GAMMA	TOT KERMA
7.000E 00	1.910E 07	2.360E 05	2.955E 07	2.979E 07	4.889E 07
2.700E 01	2.270E 06	1.000E 05	1.873E 06	1.973E 06	4.243E 06
6.000E 01	4.240E 05	3.700E 04	3.339E 05	3.709E 05	7.949E 05
1.070E 02	1.170E 05	1.460E 04	8.746E 04	1.021E 05	2.191E 05
1.670E 02	3.740E 04	6.260E 03	2.843E 04	3.469E 04	7.209E 04
2.400E 02	1.290E 04	2.600E 03	1.036E 04	1.296E 04	2.586E 04
3.270E 02	4.450E 03	1.080E 03	3.977E 03	5.057E 03	9.507E 03
4.270E 02	1.540E 03	4.460E 02	1.580E 03	2.026E 03	3.566E 03
5.400E 02	5.500E 02	1.820E 02	6.365E 02	8.185E 02	1.368E 03
6.670E 02	1.690E 02	7.660E 01	2.545E 02	3.311E 02	5.001E 02
8.070E 02	5.830E 01	3.090E 01	1.008E 02	1.317E 02	1.900E 02
9.600E 02	1.910E 01	1.320E 01	3.926E 01	5.246E 01	7.156E 01
1.127E 03	6.020E 00	5.390E 00	1.487E 01	2.026E 01	2.628E 01
1.307E 03	2.040E 00	2.080E 00	5.486E 00	7.566E 00	9.606E 00
1.500E 03	6.120E-01	8.350E-01	1.965E 00	2.800E 00	3.412E 00

Table 8 : Kerma distributions for a 1-metre burst over sea.

250-METRE BURST OVER SEA			1-KTON STANDARD-FISSION-WEAPON		
RANGE (METRES)	KERMA (RADS)				
	NEUTRON	SEC GAMMA	PRI GAMMA	TOT GAMMA	TOT KERMA
7.000E 00	3.600E 04	1.360E 04	8.239E 03	2.184E 04	5.784E 04
2.700E 01	4.210E 04	1.390E 04	8.108E 03	2.201E 04	6.411E 04
6.000E 01	3.920E 04	1.300E 04	7.587E 03	2.059E 04	5.979E 04
1.070E 02	2.890E 04	1.020E 04	6.401E 03	1.660E 04	4.550E 04
1.670E 02	2.060E 04	7.220E 03	4.683E 03	1.190E 04	3.250E 04
2.400E 02	1.300E 04	4.630E 03	2.948E 03	7.578E 03	2.058E 04
3.270E 02	6.370E 03	2.390E 03	1.622E 03	4.012E 03	1.038E 04
4.270E 02	2.730E 03	1.110E 03	8.119E 02	1.922E 03	4.652E 03
5.400E 02	1.190E 03	5.090E 02	3.800E 02	8.890E 02	2.079E 03
6.670E 02	4.740E 02	2.190E 02	1.680E 02	3.870E 02	8.610E 02
8.070E 02	1.600E 02	9.120E 01	7.129E 01	1.625E 02	3.225E 02
9.600E 02	5.710E 01	3.740E 01	2.916E 01	6.656E 01	1.237E 02
1.127E 03	1.650E 01	1.610E 01	1.144E 01	2.754E 01	4.404E 01
1.307E 03	5.660E 00	6.740E 00	4.335E 00	1.108E 01	1.674E 01
1.500E 03	1.670E 00	2.480E 00	1.584E 00	4.064E 00	5.734E 00

Table 9 : Kerma distributions for a 250-metre burst over sea.

500-METRE BURST OVER SEA			1-KTON STANDARD-FISSION-WEAPON		
RANGE (METRES)	KERMA (RADS)				
	NEUTRON	SEC GAMMA	PRI GAMMA	TOT GAMMA	TOT KERMA
7.000E 00	2.460E 03	9.520E 02	6.928E 02	1.645E 03	4.105E 03
2.700E 01	2.410E 03	9.370E 02	6.891E 02	1.626E 03	4.036E 03
6.000E 01	2.340E 03	9.090E 02	6.738E 02	1.583E 03	3.923E 03
1.070E 02	2.210E 03	8.610E 02	6.341E 02	1.495E 03	3.705E 03
1.670E 02	1.970E 03	7.600E 02	5.610E 02	1.321E 03	3.291E 03
2.400E 02	1.560E 03	6.160E 02	4.554E 02	1.071E 03	2.631E 03
3.270E 02	1.030E 03	4.360E 02	3.322E 02	7.682E 02	1.798E 03
4.270E 02	6.100E 02	2.730E 02	2.171E 02	4.901E 02	1.100E 03
5.400E 02	3.470E 02	1.590E 02	1.277E 02	2.867E 02	6.337E 02
6.670E 02	1.500E 02	7.790E 01	6.804E 01	1.459E 02	2.959E 02
8.070E 02	6.340E 01	3.520E 01	3.343E 01	6.863E 01	1.320E 02
9.600E 02	2.430E 01	1.560E 01	1.532E 01	3.092E 01	5.522E 01
1.127E 03	8.950E 00	6.930E 00	6.572E 00	1.350E 01	2.245E 01
1.307E 03	3.410E 00	3.290E 00	2.669E 00	5.959E 00	9.369E 00
1.500E 03	1.030E 00	1.370E 00	1.030E 00	2.400E 00	3.430E 00

Table 10 : Kerma distributions for a 500-metre burst over sea.

750-METRE BURST OVER SEA			1-KTON STANDARD-FISSION-WEAPON		
RANGE (METRES)	KERMA (RADS)				
	NEUTRON	SEC GAMMA	PRI GAMMA	TOT GAMMA	TOT KERMA
7.000E 00	3.440E 02	1.510E 02	1.079E 02	2.589E 02	6.029E 02
2.700E 01	3.330E 02	1.490E 02	1.076E 02	2.566E 02	5.896E 02
6.000E 01	3.280E 02	1.460E 02	1.062E 02	2.522E 02	5.802E 02
1.070E 02	3.110E 02	1.400E 02	1.027E 02	2.427E 02	5.537E 02
1.670E 02	2.870E 02	1.300E 02	9.573E 01	2.257E 02	5.127E 02
2.400E 02	2.570E 02	1.160E 02	8.462E 01	2.006E 02	4.576E 02
3.270E 02	2.000E 02	9.340E 01	6.955E 01	1.629E 02	3.629E 02
4.270E 02	1.360E 02	6.720E 01	5.249E 01	1.197E 02	2.557E 02
5.400E 02	8.520E 01	4.510E 01	3.608E 01	8.118E 01	1.664E 02
6.670E 02	5.190E 01	2.800E 01	2.245E 01	5.045E 01	1.023E 02
8.070E 02	2.380E 01	1.510E 01	1.272E 01	2.782E 01	5.162E 01
9.600E 02	1.100E 01	7.230E 00	6.609E 00	1.384E 01	2.484E 01
1.127E 03	4.330E 00	3.680E 00	3.158E 00	6.838E 00	1.117E 01
1.307E 03	1.550E 00	1.550E 00	1.404E 00	2.954E 00	4.504E 00
1.500E 03	5.260E-01	6.450E-01	5.846E-01	1.230E 00	1.756E 00

Table 11 : Kerma distributions for a 750-metre burst over sea.

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ABSTRACT

Calculations of the free-field neutron and secondary gamma-ray environments generated by the detonation of tactical standard-fission-weapons have been made for air-over-ground and air-over-seawater geometries. These data have been combined with previously published calculations of the radiation environments due to the primary prompt gamma-ray component, in order to predict the total radiation intensities induced along the air-ground interface, for various heights of weapon burst.

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