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CALCULATION OF COMBAT VEHICLE PROTECTION AGAINST A RESIDUAL RAD--ETC(U)
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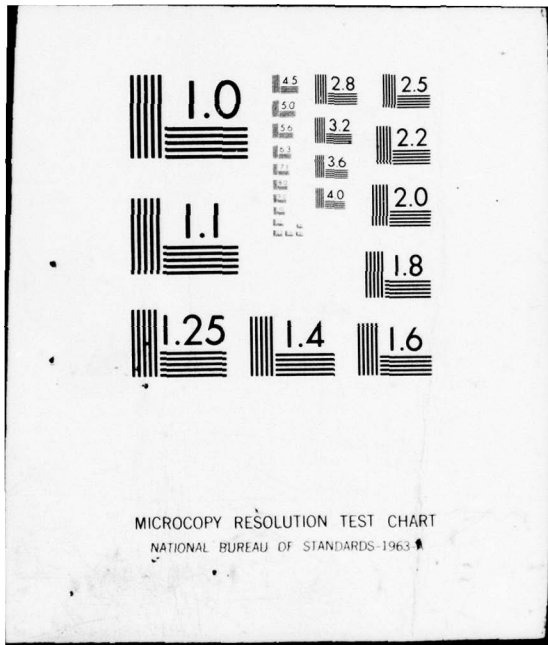
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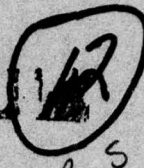
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TECHNICAL REPORT ARBRL-TR-02053

CALCULATION OF COMBAT VEHICLE PROTECTION
AGAINST A RESIDUAL RADIATION THREAT

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April 1978

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BALLISTIC RESEARCH LABORATORY ✓
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I. PURPOSE

The purpose of this report is to describe a calculational method which can be employed to provide a quantitative measure of the increased survivability of personnel in combat vehicles against the external radiation exposure threat posed by residual radiation. Comparisons with certain applicable experiments are made in order to assess the accuracy of the technique.

II. INTRODUCTION

A. Background

Residual radiation can pose a military threat. Under certain meteorological and/or weapon employment conditions, radioactive fallout from a weapon burst could be of such a localized character so as to cause areas of intense radiation. The extent and intensities of these radiation fields can be mapped by troops utilizing the appropriate equipment. Alternately, with some information on the conditions pertaining to the weapon burst and the prevailing winds, the fallout patterns can be predicted by the battle field commander.¹ Troops passing through or emplaced in these areas would be subjected to a radiation hazard. Their vulnerability can be reduced by a number of techniques which include physically removing the radioactive debris by scraping the surrounding ground or by utilizing the shielding afforded by armored vehicles. The concern here is the reduction of the fallout threat by armored vehicles.

The protection afforded by a combat vehicle against the gamma radiation from fallout can be quantified in terms of a gamma protection factor (GPF). The GPF for fallout radiation is defined as the ratio of the dose at an altitude of 3 feet in the absence of the vehicle (free field dose) to the dose at a position inside the vehicle. Clearly, the larger the overall GPF for a particular vehicle, the more protection it affords.

Heretofore, GPF values for these geometrically complicated military vehicles have been measured experimentally. One technique used to simulate the fallout threat against a variety of vehicles was a circulating point source of radiation.² These experiments modelled an envisioned scenario of an infinite-in-extent flat air/ground interface with the fallout source distributed uniformly on the ground. Two convenient

¹ J.C. Maloney and W.J. Klemm, "Department of Defense Land Fallout Prediction System", May 1975, BRL Report No. 1783, Ballistic Research Laboratory, APG-EA, MD. (AD #B004148L)

² M.A. Schmoke and W.J. Post, "Residual Radiation Shielding Characteristics of the M60A1E2 Tank", October 1973, BRL Report No. 1678, Ballistic Research Laboratory, APG-AA, MD. (AD #914673L)

isotopes, ^{60}Co and ^{137}Cs , were available to approximate the various stages in the radioactive decay of the fallout material.³ ^{60}Co , however, was used preferentially since it represents the average energy gamma radiation present in fallout at early times.

Oak Ridge National Laboratory (ORNL) developed a three dimensional Monte Carlo radiation transport code, MORSE⁴, which has the capability of handling complicated geometries via a combinatorial geometry (CG) package.⁵ MORSE is an "off-the-shelf" computer code which has been successfully employed in the cost-effective solution of a number of diverse radiation transport problems such as reactor design and the shielding of military vehicles against initial radiation.⁶ The successful application of MORSE to the problem of determining the amount of shielding afforded by combat vehicles against fallout radiation could be a viable economic alternative. It can be estimated that, relative to experimental measurements, monetary savings of about 70% could be realized in the absence of other considerations. However, since the mathematical models of the vehicles used for these calculations will have already been constructed for initial radiation calculations, the effective savings realized are even greater.

B. Calculational Approach

The scenario to be modelled in the calculations is the combat vehicle positioned at the interface of an infinite-in-extent air-over-ground environment. The source material (fallout) is assumed to be spread uniformly on the smooth interface. Figure 1 depicts the vicinity of the combat vehicle. In concert with previous experimental work, it is assumed that the gamma ray spectrum emitted by the fallout can be approximated by ^{60}Co .

A gamma ray emitted by the source distributed on the ground can interact with a crew member by following one of four paths: (a) direct,

³ R.E. REXROAD and M.A. SCHMOKE, "A Point Source Circulating System for Simulating Fallout Gamma Radiation", December 1964, NDL-TM-15, Nuclear Defense Laboratory, APG-EA, MD.

⁴ M.B. EMMETT, "The MORSE Monte Carlo Radiation Transport Code System", ORNL-4972, Oak Ridge National Laboratory, Oak Ridge, TN, 1975.

⁵ C.E. BUGART, "The Truth About Combinatorial Geometry Input", (1972), Unpublished SAI memo.

⁶ W.A. RHODES, "Development of a Code System for Determining Radiation Protection of Armored Vehicles", 1974, ORNL-TM-4664, Oak Ridge National Laboratory, Oak Ridge, TN.

GAMMA RADIATION ~~~~~>

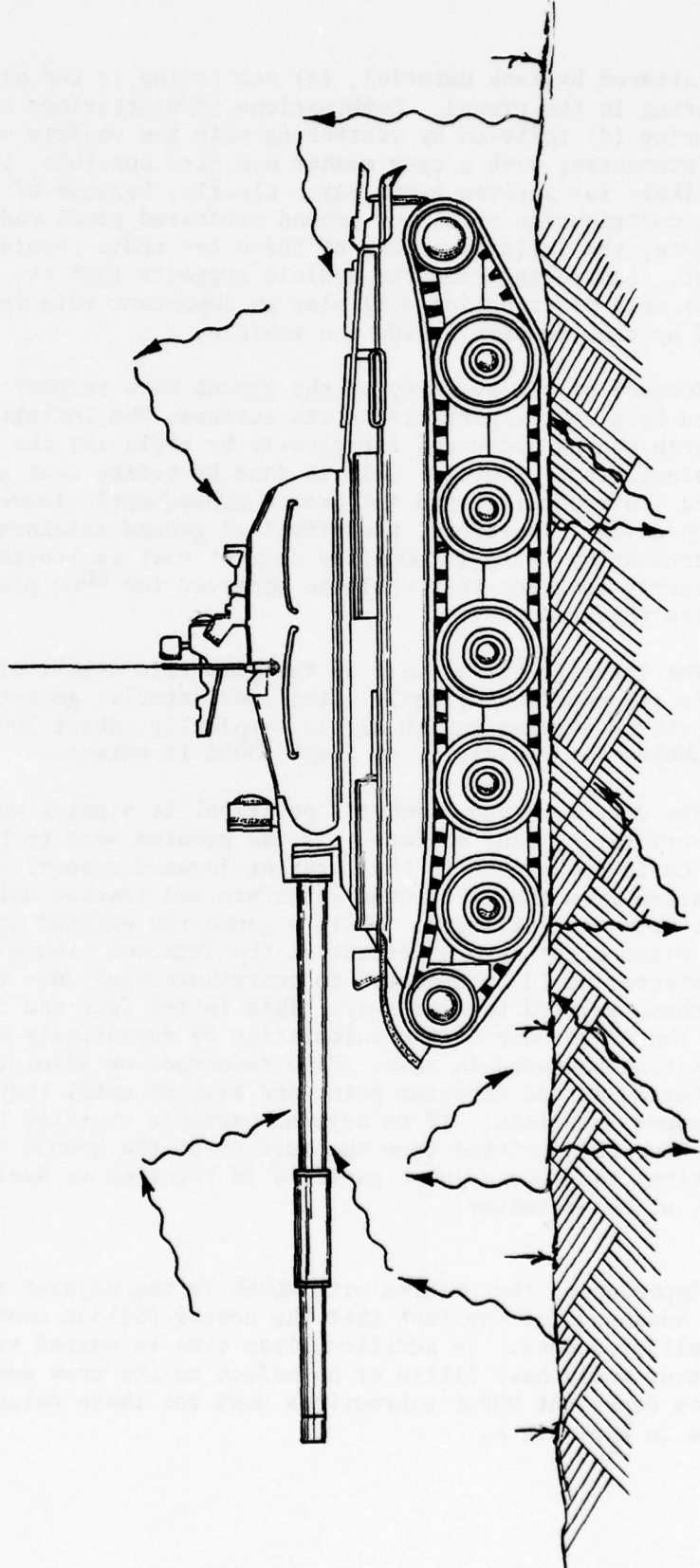


Figure 1. Vehicle in a Fallout Field.

(b) scattered by tank material, (c) scattering in the air or (d) scattering in the ground. Combinations of scatterings such as a ground scattering (d) followed by scattering with the vehicle material (b) before interacting with a crew member are also possible, but usually are less likely for a given gamma ray. Clearly, because of the possibility of the contribution of air or ground scattered gamma radiation to delivered dose, the infinite extent of these two media should be taken into account. Scattering from the vehicle suggests that its total mass as well as mass distribution will play an important role in the dose received by crew members inside the vehicle.

Because of the symmetry of the ground with respect to a gamma ray emitted by a source particle on its surface, the infinite thickness of the earth can be accounted for exactly by replacing the earth with an equivalent planar source. This is done by noting that gamma rays emitted isotropically into the ground subsequently leave the ground isotropically. Therefore, the effect of ground thickness can be taken into account by using a "modified source" that is isotropic and has the same energy spectrum that would be observed for ^{60}Co placed on earth of infinite thickness.

The infinite air as well as the geometric detail of the combat vehicle are modelled directly using combinatorial geometry. The mean free path of a gamma ray in air is, typically, about 300m. The air surrounding the vehicle is at least 3000m in extent.

The detector (crew member's position) is a point while the source is a very large plane surface. If the problem were to be treated via Monte Carlo techniques in the straight forward manner, a gamma-ray would be started from the air/ground interface and tracked while its effect on the dose was estimated. While a gamma ray emitted anywhere on this large plane might have an effect at the detector, those emitted near the detector would be expected to contribute more dose to that detector than those emitted farther away. This latter fact can be used to improve the efficiency of the calculation by essentially performing the calculation backward in time. Time-reversed, or adjoint, particles are started at the detector point and tracked until they cross the air/ground interface. If an adjoint particle crossing the interface would have been emitted from the surface of the ground (due to fallout radiation) then the adjoint particle is recorded as having had an effect at the detector.

Approaching the problem with MORSE in the adjoint mode automatically takes advantage of the fact that the nearer fallout contributes most to the delivered dose. In addition, less time is wasted tracking gamma rays that would have little or no effect on the crew member. Several problem dependent MORSE subroutines used for these calculations are listed in Appendix A.

The gamma ray data, material cross-sections, and Auxier-Snyder fluence-to-dose conversion factors were taken from the DNA 37-21 library.⁷ The atomic composition of the air and soil are listed in Table I.

III. RESULTS

A. Ground Scattered Spectrum

Gamma rays with an isotropic distribution were started from a point source of ^{60}Co on the surface of a cube of soil one kilometre on a side. All the gamma rays exiting from the surface of the cube were scored as to energy and importance (statistical weight). These exiting gamma rays included those which scattered from within the cube of soil.

Table II contains the energy bin structure of the gamma rays from the DNA 37-21 group set. Notice that the two gamma rays of ^{60}Co , 1.17 and 1.33 MeV, are both within energy group 11. Figure 2 presents the results of the above calculation. In Figure 2 it is seen that 50% of the leakage gamma radiation has an energy equal to the primary energy group. This would be expected since half of the gamma rays are emitted away from the soil cube. Furthermore, the secondary peak at approximately 200 keV is due to backscattered radiation (large angle scattering) which has an increased probability of escaping the cube of soil.

B. Free Field Calculations

The spectrum presented in Figure 2 appears reasonable; however, another check to determine whether it will adequately represent the leakage spectrum for the case of interest can be performed. Simulated fallout fields have been studied by a number of workers.^{8,9} Reference 9 contains semi-empirical data for the free field dose rate at various heights above a fallout field simulated with a point source of ^{60}Co .

Figure 3 presents a plot of these data versus height. The line through these points is intended solely as a guide. Plotted also are

⁷ D.E. Bartine, J.R. Knight, J.V. Pace and R.W. Roussin, "Production and Testing of the DNA Few Groups Cross Section Library", October 1975, ORNL - TM-4840, Oak Ridge National Laboratory, Oak Ridge, TN.

⁸ Schumchyk, et al., "Measurements of Gamma Radiation and Gamma Spectra versus Height Above a Fallout Field Simulated with ^{60}Co ", November 1965, NDL-TR-70, Nuclear Defense Laboratory, APG-EA, MD.

⁹ Schumchyk, et al., "Scattered Radiation (Skyline) Contribution to an Open Basement Located in a Simulated Fallout Field", December 1966, NDL-TR-68, Nuclear Defense Laboratory, APG-EA, MD.

Table I. Atomic Composition of Air and Soil

<u>Element</u>	<u>Atomic Density (atoms/barn-cm)</u>
Air	
Oxygen	1.1229-5*
Nitrogen	4.19948-5
Argon	2.51482-7
Ground	
Oxygen	3.47950-2
Silicon	1.15967-2
Aluminum	4.88019-3
Hydrogen	9.75181-3

* Read as 1.1229×10^{-5}

Table II. Gamma Ray Energy Group Structure

<u>Group Number</u>	<u>Upper Edge (eV)</u>
1	1.4 + 7*
2	1.0 + 7
3	8.0 + 6
4	7.0 + 6
5	6.0 + 6
6	5.0 + 6
7	4.0 + 6
8	3.0 + 6
9	2.5 + 6
10	2.0 + 6
11	1.5 + 6
12	1.0 + 6
13	7.0 + 5
14	4.5 + 5
15	3.0 + 5
16	1.5 + 5
17	1.0 + 5
18	7.0 + 4
19	4.5 + 4
20	3.0 + 4
21	2.0 + 4
	1.0 + 4

* Read as 1.4×10^7

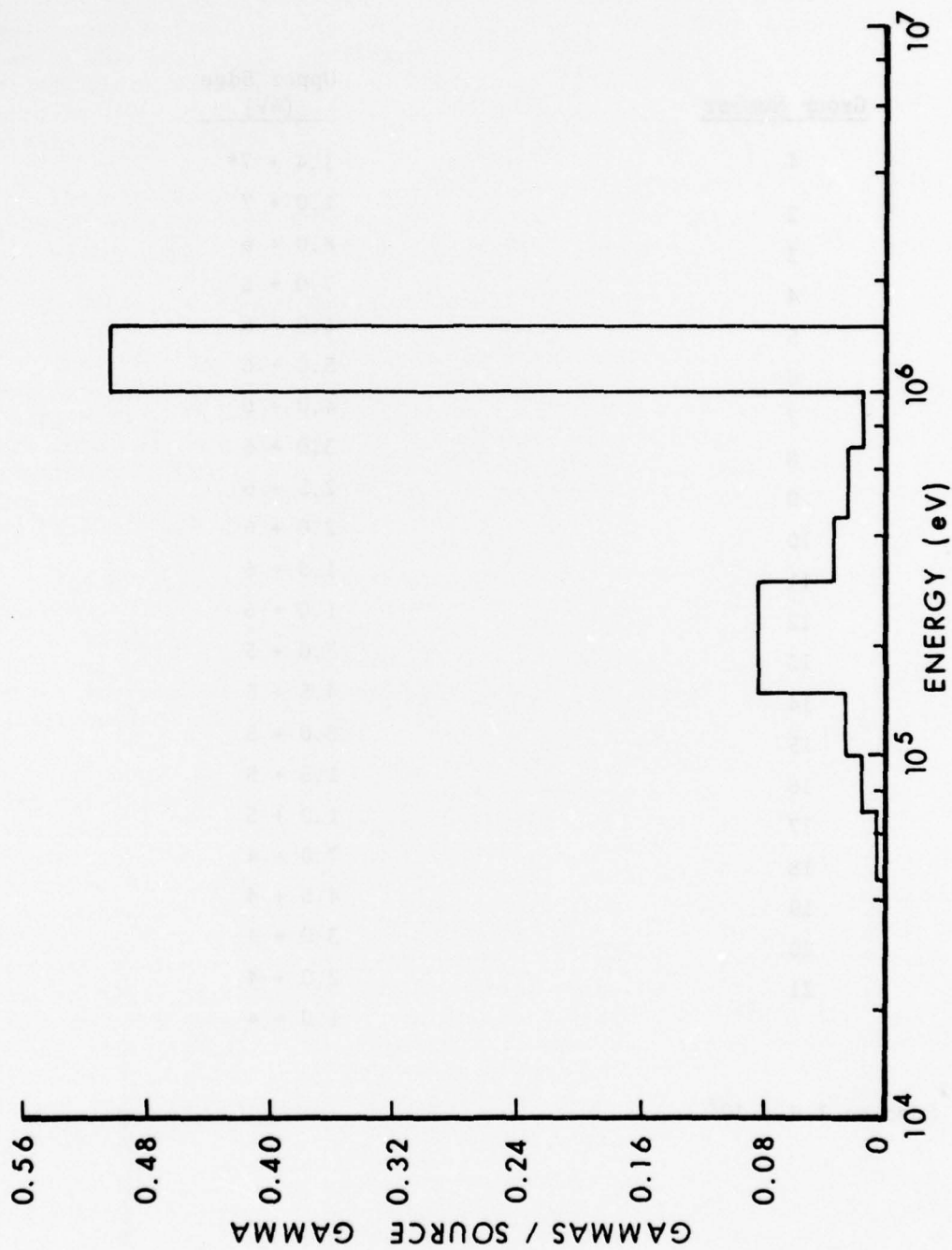


Figure 2. Gamma Spectrum from ⁶⁰Co on a Smooth Semi-Infinite Cube of Soil

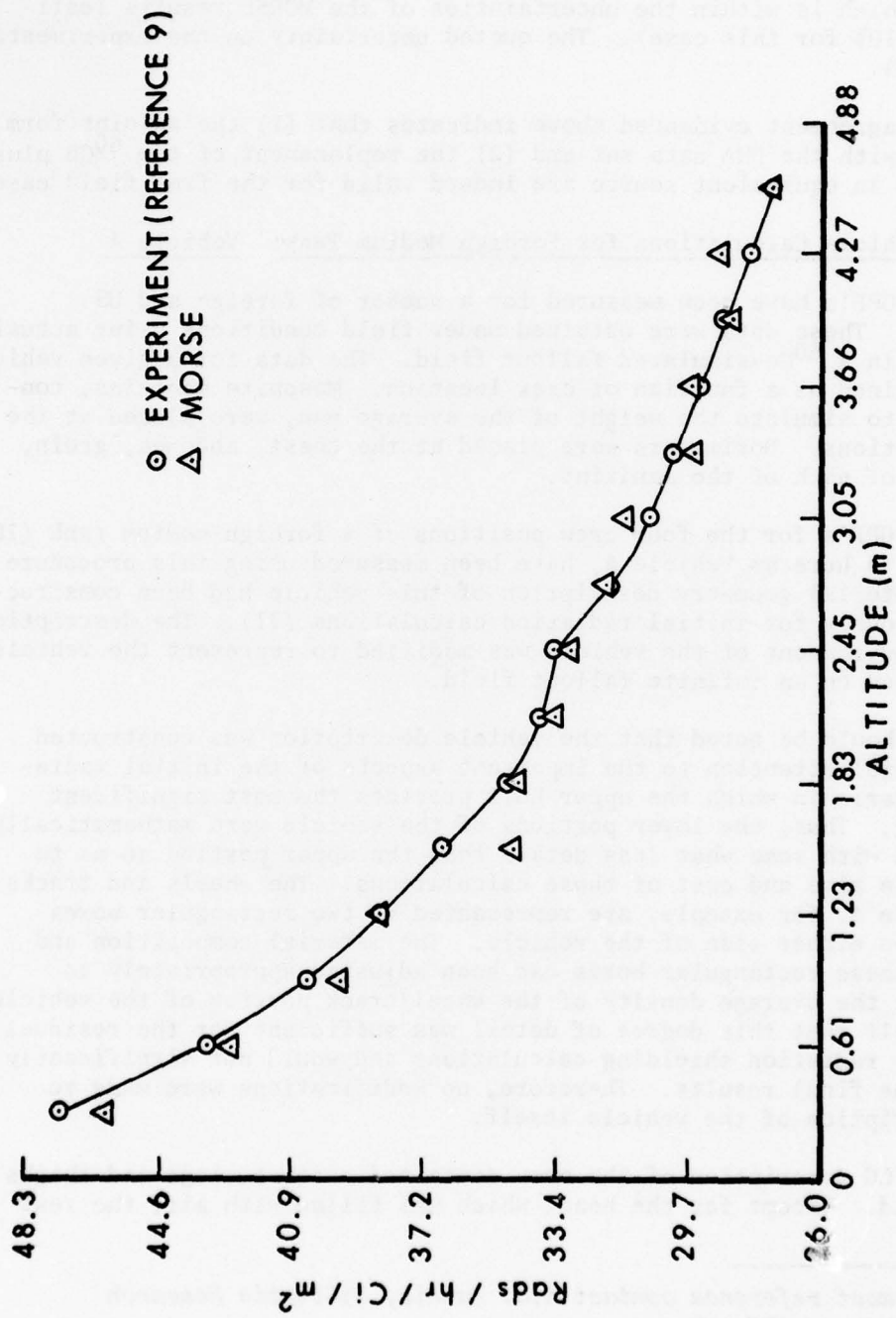


Figure 3. Dose Rate Above a ^{60}Co Simulated Fallout Field

the results of 15 adjoint MORSE calculations for the dose rate as a function of height over an infinite, smooth plane. Note that the agreement is excellent. The greatest difference (the point at five feet) is only 5% which is within the uncertainties of the MORSE results (estimated at 10% for this case). The quoted uncertainty on the experimental data is 6%.

The agreement evidenced above indicates that (1) the adjoint form of MORSE with the DNA data set and (2) the replacement of the ^{60}Co plus soil with an equivalent source are indeed valid for the free field case.

C. In-Vehicle Calculations for Foreign Medium Tank: Vehicle A

The GPF's have been measured for a number of foreign and US vehicles. These data were obtained under field conditions using actual vehicles in a ^{60}Co -simulated fallout field. The data for a given vehicle were obtained as a function of crew location. Masonite manikins, constructed to simulate the weight of the average man, were placed at the crew positions. Dosimeters were placed at the chest, abdomen, groin, and back of each of the manikins.

The GPF's for the four crew positions of a foreign medium tank (10), referred to here as Vehicle A, have been measured using this procedure. A combinatorial geometry description of this vehicle had been constructed previously for initial radiation calculations (11). The description of the environment of the vehicle was modified to represent the vehicle as situated on an infinite fallout field.

It should be noted that the vehicle description was constructed with careful attention to the important aspects of the initial radiation scenario in which the upper hull provides the most significant shielding. Thus, the lower portions of the vehicle were mathematically described with some what less detail than the upper portion so as to reduce the time and cost of those calculations. The wheels and tracks of Vehicle A, for example, are represented by two rectangular boxes located on either side of the vehicle. The material composition and mass of these rectangular boxes had been adjusted appropriately to represent the average density of the wheel/track portion of the vehicle. It was felt that this degree of detail was sufficient for the residual (fallout) radiation shielding calculations and would not significantly affect the final results. Therefore, no modifications were made to the description of the vehicle itself.

The CG description of the crew contained a torso, legs and thighs and a head. Except for the head, which was filled with air, the rest

¹⁰ For exact reference contact A.E. Rainis, Ballistic Research Laboratory, APG, MD.

¹¹ For exact reference contact A.E. Rainis, BRL, APG, MD.

of the body used the composite "man" material described in Reference 11. The GPF was calculated at four locations in and near crew members of Vehicle A: just outside the center of the chest (front), the center of the back, inside the air filled head, and mid torso. This was done to assess the effect of the GPF on the location of the detector position.

Figure 4 presents a comparison of the gamma energy spectra in-vehicle (loader's position) and free field. Note that the primary shape differences are in the low energy region below 200 keV. This type of behavior is what might be expected since the photoelectric absorption cross section for iron increases rapidly with decreasing energy below 200 keV. ¹²

The calculated values of the GPF for the above locations and the average measured values are shown in Table III. The uncertainty limits on the experimentally determined average GPFs reflect both the experimental error and the spread of the values of the GPFs measured at the different locations on the manikin. The values of the fractional standard deviation (fsd) given for the calculated values provide a calculational "figure-of-merit". That is, they are a measure only for the stochastic nature of the calculation and not necessarily an estimate of the discrepancy with the "true" value.

The mid-torso detector location is observed to compare favorably with the experimental average values. The largest observed difference for these comparisons is less than 20%, with the calculated GPFs always within the experimental uncertainty limits. Table III also shows that air-detector calculations (front, back and head) generally lie close to one another but, with one exception, are lower than the mid-torso calculations and the experimental average. However, with the exception of the driver's position, the experimental uncertainties and the calculated GPFs with their associated fsd show agreement. Note that the calculated GPFs for the mid-torso location of the gunner's and loader's positions have fsd values which are twice that of the calculations for the detectors in air. This occurs because of the location of the detector inside the mid-torso. From this viewpoint, a detector position in air is desirable. Of the three in-air locations utilized for these calculations, the center of the air head is the most easily identifiable in the combinatorial geometry description. Therefore, both for calculational convenience and ease of reproducibility, the air head location will be employed as the standard position for future calculations.

¹² J.H. Hubbell and M.J. Berger, "Photon Attenuation Absorption Coefficients: Tabulation and Discussion", September 1966, NBS 8681, National Bureau of Standards.

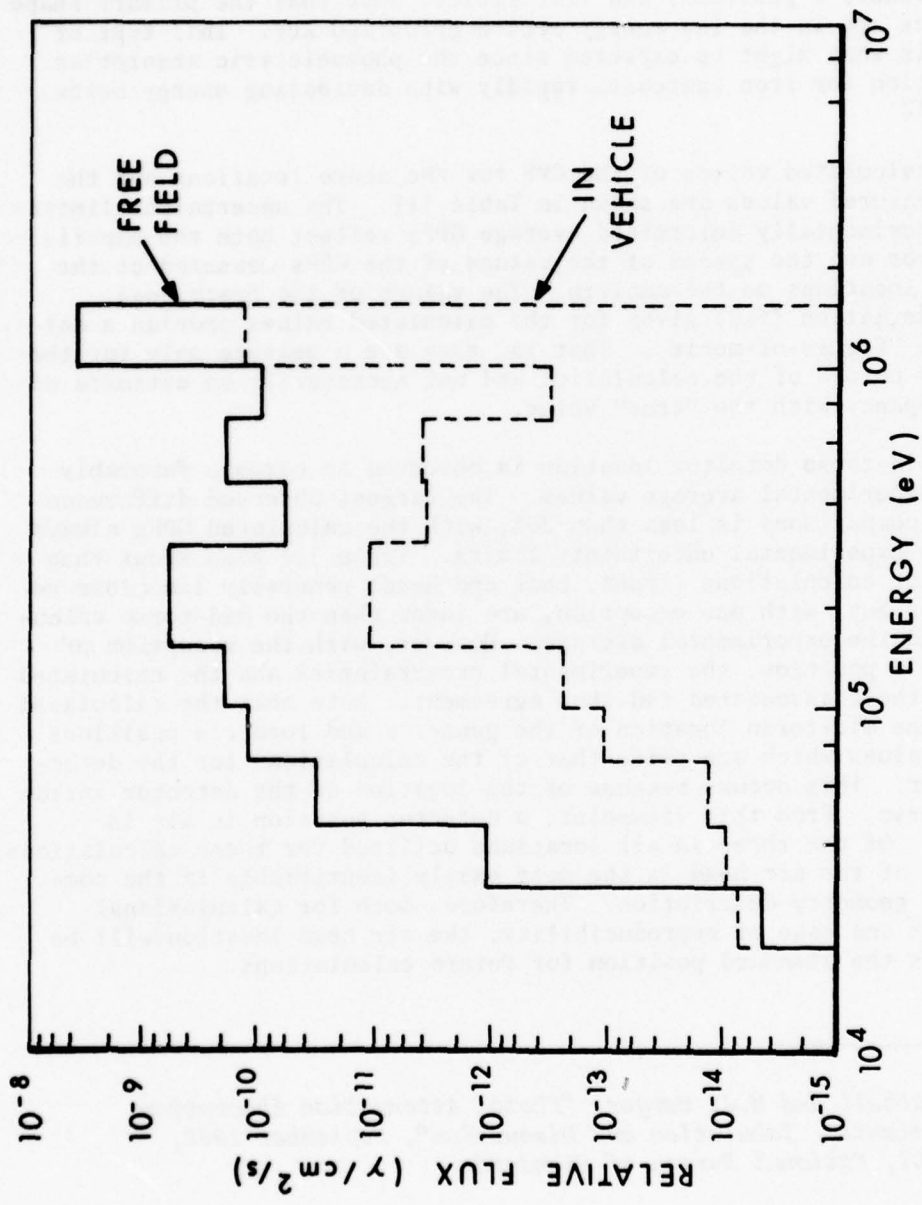


Figure 4. Free Field and In-vehicle Gamma Energy Spectra for Vehicle A.

Table III. Experimental/Calculated Values of the GPF for Vehicle A*

Crew Position		Driver	Gunner	Commander	Loader
Detector Location					
Front (Calculated)		16	26	24	23
Back (Calculated)		17	27	27	22
Head (Calculated)		16	29	26	28
Mid Torso (Calculated)		18	25**	34	25**
Mid Torso (Experimental,	***	22±18%	29±21%	33±15%	31±28%

* fsd is less than 10% for the in-vehicle dose rate calculations except as noted.

** fsd is 20% for the in-vehicle dose rate calculations.

***For exact reference contact A.E. Rainis, Ballistic Research Laboratory, APG, MD 21005.

D. In-Vehicle Calculations For Foreign Medium Tank: Vehicle B

Calculations for another vehicle were performed to further test the correlation of an air head detector location for the calculations. The values of the GPF for the crew of this vehicle (referred to as Vehicle B) have also been measured previously.¹³ Additionally, a CG description of the vehicle, previously used for initial radiation calculations, was also available.¹⁴ This description was modified only to the extent described in the previous section for Vehicle A. The results of the experiments and these calculations are presented in Table IV.

Note that the average GPF for all positions in the experiment and the calculation agree with each other despite the fact that the experimental numbers are based on detectors placed about the torso while the the detector location for the calculations is in the head. The correspondence of these values demonstrates that the GPF for an air-head detector is similiar to the average GPF of detectors placed about the body. This reinforces the use of the air-head location for future calculations.

Examining the GPF values for the individual crew positions, one finds that the calculated values for the driver position appear to be low when compared to the experimental results. This may be due to limited detail of the lower portion of the vehicle. Because the location of the driver is closer to the source of radiation and the "smeared" wheels and track than the other locations, the GPF for that position would be expected to be the most sensitive to differences between the actual vehicle and the description employed for the calculations.

¹³ For exact reference, contact A.E. Rainis, Ballistic Research Laboratory, Aberdeen Proving Ground, MD.

¹⁴ For exact reference, contact A.E. Rainis, Ballistic Research Laboratory, Aberdeen Proving Ground, MD.

Table IV. Experimental/Calculated GPF's for Vehicle B

<u>Crew Position</u>	<u>Experiment</u>		<u>Calculation</u>	
	<u>Body Average</u>	<u>Range</u>	<u>Air Head</u>	<u>fsd(%)</u>
Commander	29	25-32	34	10
Loader	30	23-34	30	16
Gunner	30	20-39	33	18
Driver	24	20-26	15	11
Overall Average	28		28	

IV. CONCLUSIONS

The described calculational technique can be employed to calculate values of the GPF for the crew of military vehicles. Using the comparisons between calculations and experiments on the same vehicles, a conservative confidence limit of 20% can be assigned to the calculated values of the GPF. For convenience, the air-head is adopted as the detector location for future calculations.

APPENDIX A

Problem Dependent MORSE Subroutines

The computer code, MORSE, used for these calculations was, in the main, the standard version distributed by RSIC.⁴ Several subroutines necessary for dose estimation are problem dependent and have to be user supplied. The subroutines peculiar to this problem are included in Tables A1-A3.

Table A1. MORSE Subroutine BANKR

```

SUBROUTINE BANKR(NBNKID)
C DO NOT CALL EUCLID FROM BANKR(7)
COMMON /APOLLO/ AGSTRT,DFD,DEADWT(5),ETA,ETATH,ETAUSD,UINP,VINP,
1 WINP,STSTRT,XSTRT,YSTRT,ZSTRT,TCUT,XTRA(10),
2 IO,I1,MEDIA,IADJM,ISBIAS,ISOUR,ITERS,ITIME,ITSTR,LOCWTS,LOCFML,BANKR 40
3 LOCEPR,LOCNSC,LOCFSN,MAXGP,MAXTIM,MEDALB,MGPREG,MXREG,NALB, BANKR 50
4 NDEAD(5),NEWNM,NGEOM,NGPWT1,NGPQT2,NGPQT3,NGPQTG,NGPQTN,NITS, BANKR 60
5 NKCALC,NKILL,NLAST,NMEN,NMGP,NMOST,NMTG,NOLEAK,NORMG,NPAST, BANKR 70
6 NPSC(13),NQUIT,NSIDL,NSOUR,NSPLT,NSTRT,NXTRA(10) BANKR 80
COMMON /NUTRON/ NAME,NAMEX,IG,IGO,NMED,MEDOLD,NREG,U,V,W,UOLD,VOLD,BANKR 90
1 ,WOLD,X,Y,Z,XOLD,YOLD,ZOLD,WATE,OLDWT,WTBC,BLZNT,BLZON,AGE,OLDAGE,BANK 100
NBNK = NBNKID BANK 110
IF (NBNK) 100,100,140 BANK 120
NBNK = NBNK + 5 BANK 130
GO TO (104,103,102,101),NBNK BANK 140
101 CALL STRUN BANK 150
CALL HELP(4HSTRU,1,1,1,1)
RETURN
102 NBAT = NITS - ITERS BANK 160
NSAVE = NMEM BANK 170
CALL STBTCH(NBAT) BANK 180
C NBAT IS THE BATCH NO. LESS ONE BANK 190
RETURN
103 CALL NBATCH (NSAVE)
C NSAVE IS THE NO. OF PARTICLES STARTED IN THE LAST BATCH
RETURN
C CALL WRTCD(NBNK,1,NMGP,NMPQTN,NGPQTG,IADJM)
BANK 200
BANK 210
BANK 220

```

Table A1. MORSE Subroutine BANKR (Continued)

BANK 230
BANK 240

104 CONTINUE
CALL NRUN(NITS,NQUIT)
NITS IS THE NO. OF BATIC HES COMPLETED IN THE RUN JUST COMPLETED
NQUIT .GT. 1 IF MORE RUNS REMAIN
.EQ. 1 IF THE LAST SCHEDULED RUN HAS BEEN COMPLETED
IS THE NEGATIVE OF THE NO. OF COMPLETE RUNS WHEN AN
EXECUTION TIME KILL OCCURS

BANK 250
BANK 260

RETURN
140 GO TO (1,2,3,4,5,6,7,8,9,10,11,12,13),NBNK
C NBNKID COLL TYPE BANKR CALL NBNKID COLL TYPE BANKR CALL
C 1 SOURCE YES (MSOUR) 2 SPLIT NO (TESTW)
C 3 FISSION YES (FPROB) 4 GAMGEN YES (GSTORE)
C 5 REAL COLL YES (MORSE) 6 ALBEDO YES (MORSE)
C 7 BDRYX YES (NXTCOL) 8 ESCAPE YES (NXTCOL)
C 9 E-CUT NO (MORSE) 10 TIME KILL NO (MORSE)

Table A1 MORSE Subroutine BANKR (Continued)

C 11	R R KILL	NO (TESTW)	12	R R SURV	NO (TESTW)	
C 13	GAMLOST	NO (GSTORE)				
C 1	CALL SDATA					BANK 290
1	RETURN					BANK 300
2	RETURN					
3	RETURN					
C 4	CALL SGAM					
4	RETURN					
C 5	CALL RELCOL					BANK 340
5	RETURN					
6	RETURN					
C						
C * * *	USE HOME MADE SURFACE CROSSING ESTIMATOR.					
7	CALL SXE					BANK 360
8	RETURN					BANK 370
9	RETURN					BANK 380
10	RETURN					BANK 390
11	RETURN					BANK 400
12	RETURN					BANK 410
13	RETURN					BANK 420
	END					

Table A2. MORSE Subroutine

```

FUNCTION DIREC(X)
COMMON /USER/ DUM(9), IO, I1, IDUM(12)
COMMON /NUTRON/ NAME, NAMEX, IG, IGO, NMED, MEDOLD, NREG, U, V, W, UOLD, VOLD
1 WOLD, XT, Y, Z, XOLD, YOLD, ZOLD, WATE, OLDWT, WTBC, BLZNT, BLZON, AGE, OLDAGE
DATA ICALL/1/
IF (ICALL) 10,10,5
5 ICALL = 0
WRITE (10,1000)
FORMAT( YOU ARE USE THE VERSION OF DIREC WHICH BIASES THE ',
$ PARTICLES TO THE -Z DIRECTION ACCORDING TO W (DIR. COS).')
10 DIREC = -1. W
RETURN
END
DIREC 10
DIREC 20
DIREC 30
DIREC 40
DIREC 50
DIREC 60
DIRE 100
DIRE 110

```

Table A3. MORSE Subroutine SXE

```

SUBROUTINE SXE
SURFACE CROSSING ESTIMATOR FOR MORSE. INFINITE AIR/PLANE CASE
C*****
C ASSUMES A SQUARE SCORING SURFACE OF DIMENSION 'RAD' (=3.0+8 CM)
C WHICH IS PARALLEL TO THE X-Y PLANE AT A HEIGHT 'ZC' (=0.0) AND
C IS MADE UP OF MEDIUM 1000. THE AREA IS RAD**2
C*****
COMMON /PDET/ ND, NNE, NE, NT, NA, NRESP, NEX, NEXND, NEND, NDNR, NNTNR, NNTNE,
1 NAME, NTNDNR, NTNEND, NANEND, LOCRSP, LOCXD, LOCIB, LOCCO, LOCT, LOCUD,
2 LOCSD, LOCQE, LOCQT, LOCQTE, LOCQAE, LMAX, EFIRST, EGTOP
COMMON /NUTRON/ NAME, NAMEX, IG, ICO, NMED, MEDOLD, NREG, U, V, W, UOLD, VOLD
1 WOLD, X, Y, Z, XOLD, YOLD, ZOLD, WATE, OLDWT, WTBC, BLZNT, BLZON, AGE, OLDAGE
COMMON/DETCUT/NDC
COMMON NL(1)
DATA RAD, ZC, AREA /3.0E8 0.005 9.0E16/
C * * * CHECK TO SEE IF CROSSING IS FOR DETECTOR SURFACE.
IF((Z-ZC).GT.0.0)GO TO 1
C * * * COS IS ABS(N*OMEGA) UNLESS IT IS A GRAZING ANGLE.
COS=ABS(H)
IF (COS.LT.0.01) COS=0.005
C * * * CALCULATE FLUENCE ESTIMATE.
CON = WATE/AREA/COS
C * * * STORE ESTIMATE AND ACCUMULATE THE NUMBER OF SAME.
CALL FLUXST(1, IG, CON, 0, 0, 0, 0, 1)
NL(LOCXD+6*ND+1)=NL(LOCXD+6*ND+1)+1
1
RETURN
END

```


Appendix B. Run Stream for a Typical Calculation (Continued)

ARB	6	-20.320	80.010	168.910	109.220	35.560	146.050
		129.540	41.910	97.790	-20.320	120.650	97.790
		-20.320	80.010	97.790	109.220	35.560	97.790
		129.540	41.910	97.790	-20.320	120.650	97.790
		1265.000	4158.000	3267.000	5678.000	4128.000	3247.000
ARB	7	-20.320	-85.090	168.910	109.220	-40.640	146.050
		129.540	-46.990	97.790	-20.320	-125.730	97.790
		-20.320	-85.090	97.790	109.220	-40.640	97.790
		129.540	-46.990	97.790	-20.320	-125.730	97.790
		1265.000	4158.000	3267.000	5678.000	4128.000	3247.000
ARB	8	-20.320	-76.200	164.973	93.980	-33.020	140.970
		93.980	27.940	140.970	-20.320	71.120	164.973
		-20.320	-76.790	97.790	93.980	-33.020	97.790
		93.980	27.940	97.790	-20.320	71.120	97.790
		1234.000	5678.000	3487.000	1265.000	2376.000	1485.000
ARB	9	93.980	27.940	140.970	93.980	-33.020	140.970
		111.760	-43.180	97.790	111.760	38.100	97.790
		93.980	27.940	97.790	93.980	-33.020	97.790
		111.760	-43.180	97.790	111.760	38.100	97.790
ARB	10	1234.000	1265.000	3456.000	3267.000	4518.000	4518.000
		-20.320	71.120	164.973	93.980	27.940	140.970
		111.760	38.100	97.790	-20.320	109.220	97.790
		-20.320	71.120	97.790	93.980	27.940	97.790
		111.760	38.100	97.790	-20.320	109.220	97.790
		1265.000	4158.000	3267.000	5678.000	4128.000	3247.000
ARB	11	-20.320	-76.200	164.973	93.980	-33.020	140.970
		111.760	-43.180	97.790	-20.320	-114.300	97.790
		-20.320	-76.200	97.790	93.980	-33.020	97.790
		111.760	-43.180	97.790	-20.320	-114.300	97.790
		1265.000	4158.000	3267.000	5678.000	4128.000	3247.000

Appendix B. Run Stream for a Typical Calculation (Continued)

TRC	12	31.750	-2.540	125.222	450.596	.000	.000
		15.240	6.350	.000	.000	.000	.000
RCC	13	31.750	-2.540	125.222	450.596	.000	.000
		5.004	.000	.000	.000	.000	.000
RCC	14	91.440	.000	94.615	.000	.000	3.175
		91.440	.000	.000	.000	.000	.000
TRC	15	.000	.000	97.790	.000	.000	-17.780
		125.730	100.584	.000	.000	.000	.000
ARB	16	243.840	93.980	.000	243.840	93.980	63.398
		294.005	90.932	34.036	294.005	90.932	34.036
		243.840	-93.980	.000	243.980	-93.980	63.398
		294.005	-90.932	34.036	294.005	-90.932	34.036
ARB	17	3124.000	7658.000	1375.000	2376.000	1265.000	1265.000
		243.840	88.900	12.192	243.840	88.900	52.222
		275.717	88.900	33.401	275.717	88.900	33.401
		243.840	-88.900	12.192	243.840	-88.900	52.222
		275.717	-88.900	33.401	275.717	-88.900	33.401
ARB	18	3124.000	7658.000	1375.000	2376.000	1265.000	1265.000
		243.840	100.584	.000	243.840	100.584	63.398
		177.800	100.584	102.057	177.800	100.584	.000
		243.840	-100.584	.000	243.840	-100.584	63.398
		177.800	-100.548	102.057	177.800	-100.584	.000
ARB	19	1234.000	5678.000	3487.000	1265.000	2376.000	1485.000
		243.840	92.710	2.032	243.840	92.710	52.222
		177.800	92.710	90.881	177.800	92.710	2.032
		243.840	-92.710	2.032	243.840	-92.710	52.222
		177.800	-92.710	90.881	177.800	-92.710	2.032
BOX	20	1234.000	5678.000	3487.000	1265.000	2376.000	1485.000
		177.800	-100.584	.000	-410.972	.000	.000
		.000	201.168	.000	.000	.000	97.790
BOX	21	177.800	-92.710	2.032	-410.972	.000	.000
		.000	185.420	.000	.000	.000	92.583

Appendix B. Run Stream for a Typical Calculation (Continued)

ARB	22	-233.172	100.584	97.790	-311.912	100.584	97.790
		-286.004	100.584	17.526	-233.172	100.584	.000
		-233.172	-100.584	97.790	-311.912	-100.584	97.790
		-286.004	-100.584	17.526	-233.172	-100.584	.000
ARB	23	1234.000	5678.000	3487.000	1265.000	2376.000	1485.000
		-233.172	92.710	94.615	-306.832	92.710	94.615
		-281.610	92.710	18.034	-233.172	92.710	2.032
		-233.172	-92.710	94.615	-306.832	-92.710	94.615
		-281.610	-92.710	18.034	-233.172	-92.710	2.032
BOX	24	1234.000	5678.000	3487.000	1265.000	2376.000	1485.000
		-124.460	-92.710	94.615	.762	.000	.000
		.000	185.420	.000	.000	.000	-92.583
RCC	25	184.05	-152.527	-1.762	0.	305.054	0.
		40.386					
RCC	26	74.77	-152.527	-1.762	0.	305.054	0.
		40.386					
RCC	27	-20.574	-152.527	-1.762	0.	305.054	0.
		40.386					
RCC	28	-105.918	-152.527	-1.762	0.	305.054	0.
		40.386					
RCC	29	-193.04	-152.527	-1.762	0.	305.054	0.
		40.386					
RPP	30	-240.	230.	-111.887	111.887	-45.	40.
BOX	31	-5.842	12.700	150.622	37.592	.000	.000
		.000	-30.480	.000	.000	.000	-40.132
BOX	32	-20.320	127.000	97.790	127.000	.000	.000
		.000	-254.000	.000	.000	.000	72.000
BOX	33	208.280	-21.590	9.906	-119.380	.000	.000
		.000	30.480	.000	.000	.000	59.436
BOX	34	-52.070	-72.390	11.430	-53.340	.000	.000
		.000	-17.018	.000	.000	.000	71.120

Appendix B. Run Stream for a Typical Calculation (Continued)

ARB	35	274.320	8.890	32.258	209.550	8.890	70.866
		209.550	8.890	9.906	239.522	8.890	9.906
		274.320	-91.440	32.258	209.550	-91.440	70.866
		209.550	-91.440	9.906	239.522	-91.440	9.906
		1234.000	5678.000	2376.000	1265.000	3487.000	1485.000
BOX	36	209.550	-21.590	70.866	-57.150	.000	.000
		.000	-69.850	.000	.000	.000	-60.960
BOX	37	-168.148	76.200	31.750	31.496	.000	.000
		.000	-127.000	.000	.000	.000	-19.812
ARB	38	-139.700	76.200	57.150	-165.100	76.200	57.150
		-165.100	-50.800	57.150	-139.700	-50.800	57.150
		-125.730	76.200	31.750	-179.070	76.200	31.750
		-179.070	-50.800	31.750	-125.730	-50.800	31.750
		1234.000	5678.000	1265.000	2376.000	3487.000	4158.000
RCC	39	-223/520	76.200	31.750	.000	-152.400	.000
		27.940	.000	.000	.000	.000	.000
ARB	40	-258.318	82.804	94.615	-306.832	82.804	94.615
		-258.750	82.804	33.020	-258.318	82.804	33.020
		-258.318	68.580	94.615	-306.832	68.580	94.615
		-258.750	27.940	33.020	-258.318	27.940	33.020
		1234.000	5678.000	1265.000	2376.000	3487.000	1485.000
BOX	41	-264.160	-102.870	93.980	185.928	.000	.000
		.000	-55.880	.000	.000	.000	-19.050
BOX	42	100.330	-102.870	93.980	90.170	.000	.000
		.000	-55.880	.000	.000	.000	-19.050
BOX	43	5.080	-125.222	93.980	50.292	.000	.000
		.000	-32.258	.000	.000	.000	-19.050
RCC	44	69.088	-29.210	65.278	70.104	.000	.000
RCC	45	69.088	-29.210	48.768	70.104	.000	.000
		6.452	.000	.000	.000	.000	.000
RCC	46	69.088	-29.210	33.020	70.104	.000	.000
		6.452	.000	.000	.000	.000	.000

Appendix B. Run Stream for a Typical Calculation (Continued)

RCC	47	69.088	-29.210	17.526	70.104	.000
		6.452	.000	.000	.000	.000
RCC	48	69.088	-44.450	80.772	70.104	.000
		6.452	.000	.000	.000	.000
RCC	49	69.088	-44.450	65.278	70.104	.000
		6.452	.000	.000	.000	.000
RCC	50	69.088	-44.450	48.768	70.104	.000
		6.452	.000	.000	.000	.000
RCC	51	69.088	-44.450	33.020	70.104	.000
		6.452	.000	.000	.000	.000
RCC	52	69.088	-44.450	17.526	70.104	.000
		6.452	.000	.000	.000	.000
RCC	53	69.088	-61.468	80.772	70.104	.000
		6.452	.000	.000	.000	.000
RCC	54	69.088	-61.468	65.278	70.104	.000
		6.452	.000	.000	.000	.000
RCC	55	69.088	-61.468	48.768	70.104	.000
		6.452	.000	.000	.000	.000
RCC	56	69.088	-61.468	33.020	70.104	.000
		6.452	.000	.000	.000	.000
RCC	57	69.088	-61.468	17.526	70.104	.000
		6.452	.000	.000	.000	.000
RCC	58	69.088	-76.200	71.882	70.104	.000
		6.452	.000	.000	.000	.000
RCC	59	69.088	-76.200	56.642	70.104	.000
		6.452	.000	.000	.000	.000
RCC	60	69.088	-76.200	40.386	70.104	.000
		6.452	.000	.000	.000	.000
RCC	61	69.088	-76.200	24.130	70.104	.000
		6.452	.000	.000	.000	.000
RCC	62	53.340	-82.804	64.008	-70.104	.000
		6.452	.000	.000	.000	.000

Appendix B. Run Stream for a Typical Calculation (Continued)

RCC 63	-38.100	-82.804	48.514	70.104	.000
	6.452	.000	.000	.000	.000
RCC 64	53.340	-82.804	32.766	-70.104	.000
	6.452	.000	.000	.000	.000
RCC 65	-38.100	-82.804	16.510	70.104	.000
	6.452	.000	.000	.000	.000
RCC 66	-81.280	85.090	59.182	70.104	.000
	6.452	.000	.000	.000	.000
RCC 67	79.502	85.090	48.006	-70.104	.000
	6.452	.000	.000	.000	.000
RCC 68	-91.948	30.480	79.502	.000	-70.104
	6.452	.000	.000	.000	.000
RCC 69	-84.328	30.480	66.040	.000	-70.104
	6.452	.000	.000	.000	.000
RCC 70	-100.076	-60.960	66.040	.000	70.104
	6.452	.000	.000	.000	.000
RCC 71	-84.328	-60.960	50.800	.000	70.104
	6.452	.000	.000	.000	.000
RCC 72	-100.076	30.480	50.800	.000	-70.104
	6.452	.000	.000	.000	.000
RCC 73	-84.328	30.480	36.068	.000	-70.104
	6.452	.000	.000	.000	.000
RCC 74	-100.076	-60.960	36.068	.000	70.104
	6.452	.000	.000	.000	.000
RCC 75	-91.948	-60.960	22.860	.000	70.104
	6.452	.000	.000	.000	.000
RCC 76	-107.950	30.480	22.860	.000	-70.104
	6.452	.000	.000	.000	.000
RCC 77	-100.076	30.480	9.906	.000	-70.104
	6.452	.000	.000	.000	.000

Appendix B. Run Stream for a Typical Calculation (Continued)

RCC	78	-115.570	-60.960	9.906	.000	70.104	.000
RCC	79	6.452	.000	.000	.000	.000	.000
RCC	80	-69.850	-60.960	25.400	.000	70.104	.000
RCC	81	6.452	.000	.000	.000	.000	.000
RCC	82	-89.408	-81.280	109.220	68.148	-16.408	.000
RCC	83	6.452	.000	.000	.000	.000	.000
RCC	84	-86.360	-66.040	127.000	68.148	-16.408	.000
RCC	85	6.452	.000	.000	.000	.000	.000
RCC	86	-85.090	-37.592	152.908	.000	70.104	.000
RCC	87	6.452	.000	.000	.000	.000	.000
RCC	88	-96.520	32.512	144.780	.000	-70.104	.000
RCC	89	6.452	.000	.000	.000	.000	.000
RCC	90	-103.632	-37.592	132.588	.000	70.104	.000
RCC	91	6.452	.000	.000	.000	.000	.000
RCC	92	-109.220	32.512	118.872	.000	-70.104	.000
RCC	93	6.452	.000	.000	.000	.000	.000
RCC	94	-113.030	32.512	104.394	.000	-70.104	.000
RCC	95	6.452	.000	.000	.000	.000	.000
RCC	96	-60.960	49.530	145.890	10.000	.000	.000
RCC	97	3.175	31.750	135.890	20.320	.000	.000
RCC	98	-60.960	35.560	.000	.000	.000	-63.500
RCC	99	3.175	28.575	135.890	35.560	.000	-61.595
RCC	100	-60.960	70.485	.000	.000	.000	.000
RCC	101	3.175	.000	135.890	35.560	.000	-61.595
RCC	102	-50.800	38.100	.000	.000	.000	.000
RCC	103	6.350	.000	78.740	33.020	.000	.000
RCC	104	-50.800	.000	.000	.000	.000	.000
RCC	105	6.350	60.960	78.740	33.020	.000	.000
RCC	106	-21.590	.000	.000	.000	.000	.000
RCC	107	3.810	38.100	78.740	.000	.000	.000
RCC	108		.000	.000	.000	.000	-35.560
RCC	109						.000

Appendix B. Run Stream for a Typical Calculation (Continued)

RCC 94	-21.590	60.960	78.740	.000	.000	-35.560
BOX 95	3.810	.000	.000	.000	.000	.000
BOX 96	-35.560	53.020	72.390	-30.480	.000	.000
SPII 97	.000	33.020	.000	.000	.000	-2.794
BOX 98	-71.374	30.480	110.998	-3.048	.000	.000
RCC 99	.000	38.100	.000	.000	.000	5.080
RCC 100	-4.318	49.530	138.270	10.000	.000	.000
RCC 101	-14.478	31.750	128.270	20.320	.000	.000
RCC 102	.000	35.560	.000	.000	.000	-63.000
RCC 103	-4.318	28.575	128.270	61.595	.000	-35.560
RCC 104	3.175	.000	.000	.000	.000	.000
RCC 105	-4.318	70.485	128.270	61.595	.000	-35.560
RCC 106	3.175	.000	.000	.000	.000	.000
RCC 107	5.842	38.100	71.120	33.020	.000	.000
RCC 108	6.350	.000	.000	.000	.000	.000
RCC 109	5.843	60.960	71.120	33.020	.000	.000
RCC 110	6.350	.000	.000	.000	.000	.000
RCC 111	35.052	38.100	71.120	.000	.000	-35.560
BOX 105	3.810	.000	.000	.000	.000	.000
BOX 106	35.052	60.960	71.120	.000	.000	.000
BOX 107	3.810	31.750	64.516	30.480	.000	-35.560
BOX 108	-10.160	.000	.000	.000	.000	.000
BOX 109	.000	36.068	.000	.000	.000	-3.810
BOX 110	-48.260	-42.418	143.350	10.000	.000	.000
BOX 111	-58.420	-60.198	133.350	20.320	.000	.000
RCC 102	.000	35.560	.000	.000	.000	-63.500
RCC 103	-48.260	-63.373	133.350	61.595	.000	-35.560
RCC 104	3.175	.000	.000	.000	.000	.000
RCC 105	-48.260	-21.463	133.350	61.595	.000	-35.560
RCC 106	3.175	.000	.000	.000	.000	.000
RCC 107	-38.100	-53.848	76.200	33.020	.000	.000
RCC 108	6.350	.000	.000	.000	.000	.000
RCC 109	-38.100	-30.988	76.200	33.020	.000	.000
RCC 110	6.350	.000	.000	.000	.000	.000
RCC 111	-38.100	-30.988	76.200	33.020	.000	.000
RCC 112	6.350	.000	.000	.000	.000	.000

Appendix B. Run Stream for a Typical Calculation (Continued)

RCC	112	-8.890	-53.848	76.200	.000	.000	-35.560
		3.810	.000	.000	.000	.000	.000
RCC	113	-8.890	-30.988	76.200	.000	.000	-35.560
		3.810	.000	.000	.000	.000	.000
RCC	114	-42.672	-42.418	68.326	.000	.000	-2.540
		13.970	.000	.000	.000	.000	.000
BOX	115	-58.674	-52.578	69.850	-1.778	.000	.000
		.000	20.320	.000	.000	.000	38.100
SPII	116	143.510	58.928	78.580	10.000	.000	.000
BOX	117	133.350	41.148	68.580	20.320	.000	.000
		.000	35.560	.000	.000	.000	-62.230
RCC	118	143.510	37.973	68.580	61.595	.000	-35.560
		3.175	.000	.000	.000	.000	.000
RCC	119	143.510	79.883	68.580	61.595	.000	-35.560
		3.175	.000	.000	.000	.000	.000
RCC	120	153.670	47.498	12.700	33.020	.000	.000
		6.350	.000	.000	.000	.000	.000
RCC	121	153.670	70.358	12.700	33.020	.000	.000
		6.350	.000	.000	.000	.000	.000
RCC	122	186.690	47.498	12.700	33.020	.000	.000
		3.810	.000	.000	.000	.000	.000
RCC	123	186.690	70.358	12.700	33.020	.000	.000
		3.810	.000	.000	.000	.000	.000
BOX	124	128.524	40.640	3.556	38.100	.000	.000
		.000	36.830	.000	.000	.000	2.540
BOX	125	128.524	40.640	12.700	4.064	.000	.000
		.000	36.830	.000	.000	.000	40.640
RCC	126	83.000	.000	-76.990	.000	.000	30.000
		5.+5	.000	.000	.000	.000	.000
RCC	127	83.000	.000	-76.990	.000	.000	246.990
		5.+5	.000	.000	.000	.000	.000

Appendix B. Run Stream for a Typical Calculation (Continued)

END	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000
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