DNA 5277H

NUCLEAR WEAPONS TARGETING, AP-550 CROM A1

Reference Manual

Horizons Technology, Inc.
7830 Clairemont Mesa Boulevard
San Diego, California 92111

1 June 1979

Handbook

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This document is a reference document and user's guide for a solid state module programmed to reproduce various targeting calculations, using a hand-held calculator. The calculations are based on methods and data from DIA's Physical Vulnerability Handbook - Nuclear Weapons. AP-550-1-2-60-INT, June 1, 1969, Unpublished.

(Continued)

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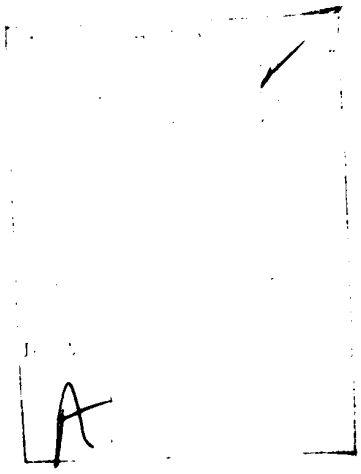
20. ABSTRACT (Continued)

The module is designed for use in the Texas Instruments programmable calculator, TI-59, with its associated PC-100 printer.

The calculator with module is capable of calculating weapon radii and probabilities of damage based on VNs, cratering phenomena, minimum safe distances, and many other calculations.

This document contains instructions for use of the module, plus annotated program listings and equations used.



CONVERSION FACTORS FOR U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

To Convert From	To	Multiply By
angstrom	meters (m)	1.000 000 X E -10
atmosphere (normal)	kilo pascal (kPa)	1.013 25 X E +2
bar	kilo pascal (kPa)	1.000 000 X E +2
barn	meter^2 (m^2)	1.000 000 X E -28
British thermal unit (thermochemical)	joule (J)	1.054 350 X E +3
calorie (thermochemical)	joule (J)	4.184 000
cal (thermochemical)/cm^2	mega joule/m^2 (MJ/m^2)	4.184 000 X E -2
curie	giga becquerel (GBq)*	3.700 000 X E +1
degree (angle)	radian (rad)	1.745 329 X E -2
degree Fahrenheit	degree kelvin (K)	$T_K = (t° f + 459.67)/1.8$
electron volt	joule (J)	1.602 19 X E -19
erg	joule (J)	1.000 000 X E -7
erg/second	watt (W)	1.000 000 X E -7
foot	meter (m)	3.048 000 X E -1
foot-pound-force	joule (J)	1.355 818
gallon (U.S. liquid)	meter^3 (m^3)	3.785 412 X E -3
inch	meter (m)	2.540 000 X E -2
jerk	joule (J)	1.000 000 X E +9
joule/kilogram (J/kg) (radiation dose absorbed)	Gray (Gy)**	1.000 000
kilotons	terajoules	4.183
kip (1000 lbf)	newton (N)	4.448 222 X E +3
kip/$inch^2$ (ksi)	kilo pascal (kPa)	6.894 757 X E +3
ktap	newton-second/m^2 ($N-s/m^2$)	1.000 000 X E +2
micron	meter (m)	1.000 000 X E -6
mil	meter (m)	2.540 000 X E -5
mile (international)	meter (m)	1.609 344 X E +3
ounce	kilogram (kg)	2.834 952 X E -2
pound-force (lbf avoirdupois)	newton (N)	4.448 222
pound-force inch	newton-meter (N·m)	1.129 848 X E -1
pound-force/inch	newton/meter (N/m)	1.751 268 X E +2
pound-force/$foot^2$	kilo pascal (kPa)	4.788 026 X E -2
pound-force/$inch^2$ (psi)	kilo pascal (kPa)	6.894 757
pound-mass (lbm avoirdupois)	kilogram (kg)	4.535 924 X E -1
pound-mass-$foot^2$ (moment of inertia)	kilogram-$meter^2$ ($kg·m^2$)	4.214 011 X E -2
pound-mass/$foot^3$	kilogram/$meter^3$ (kg/m^3)	1.601 846 X E +1
rad (radiation dose absorbed)	Gray (Gy)**	1.000 000 X E -2
roentgen	coulomb/kilogram (C/kg)	2.579 760 X E -4
shake	second (s)	1.000 000 X E -8
slug	kilogram (kg)	1.459 390 X E +1
torr (mm Hg, 0° C)	kilo pascal (kPa)	1.333 22 X E -1

*The becquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s.
**The Gray (Gy) is the SI unit of absorbed radiation.

A more complete listing of conversions may be found in "Metric Practice Guide E 380-74," American Society for Testing and Materials.

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APPENDICES - MAGNETIC CARD AUXILIARY PROGRAMS

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LIST OF TABLES

GENERAL USER INSTRUCTIONS

The documentation contained in this report consists of specific user instructions, equations and program listings for nuclear weapons targeting calculations using the Texas Instruments TI-59 hand-held programmable calculator with the DNA/AP-550 CROM A1 installed. The programs were developed by Horizons Technology, Inc. (HTI) under contract with the Defense Nuclear Agency, Contract No. DNA 001-78-C-0247

These instructions were prepared for users who have a working knowledge of the TI-59 calculators. Less experienced users will find detailed operating instructions in the TI-59 Owner's Manual.

After the instructions for each calculation, this document includes a section describing the equations used in that calculation and a section cc aining annotated program listings.

Additional program development is being continued. The purpose of this CROM and associated documentation is to examine the utility and convenience of this equipment and these programs. Selected sections of the referenced document were programmed to provide the ability to run various types of calculations. Omission of other types of calculations does not imply that they are not important or will not also be programmed in the future. Similarly, the normal test and review procedures are still in process. Issuance of these CROMs and documents prior to completion of test and review permits the possibility of programming errors. The calculated results are developed from variuos numerical representations of the available data. Two accuracy statements are required. The precision with which the referenced data are represented is typically ±5% with occasional differences of as much as ±15%. The references used claim accuracies of ±15% to 25%. The user is cautioned to refer to the referenced documents for more complete descriptions of uncertainties in data and methodologies. The approximations made in generating these data are discussed only to the extent necessary to explain the equations used. These approximations can be complex and, if not understood, can lead an inexperienced user to erroneous conclusions. These data are also valid only within limited ranges. Limits have

been imposed in most of the HTI programs to confine them within the limits of the basic data or within reasonable limits if no other restrictions pertain. The user is warned by a flashing display and termination of input printing when the limits have been exceeded.

To insert the CROM module into the calculator, follow these instructions:

1. Turn the calculator off. Replacing a module with the calculator on may cause the keyboard or display to lock out. Shorting the contacts can damage the module or the calculator.

2. Slide out the small panel covering the module compartment at the bottom on the back of the calculator. Be sure to eliminate all static charges before handling the module.

3. Remove the module initially in the calculator. The calculator may be turned over to allow the module to fall into the user's hand.

4. Insert the new module, notched end first, with the contact side down into the compartment. The module should slip effortlessly into place.

5. Replace the cover panel, securing the module against the contacts.

Descriptions of the auxiliary magnetic card programs for this CROM module are given as appendices to this document. These programs run in the turn-on state of the calculator, program 00, and call the CROM programs as subroutines. They are referred to as control programs. There are four types of control programs described in Appendices A through D.

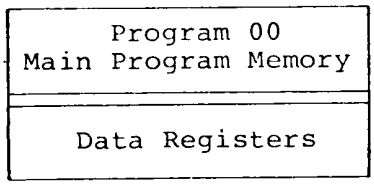
Appendix A is a demonstration code than runs CROM programs sequentially with one set of input parameters.

Appendix B provides for repetitive calculations with varying inputs, for parametric studies.

Appendix C provides for inversions of several of the CROM calculations.

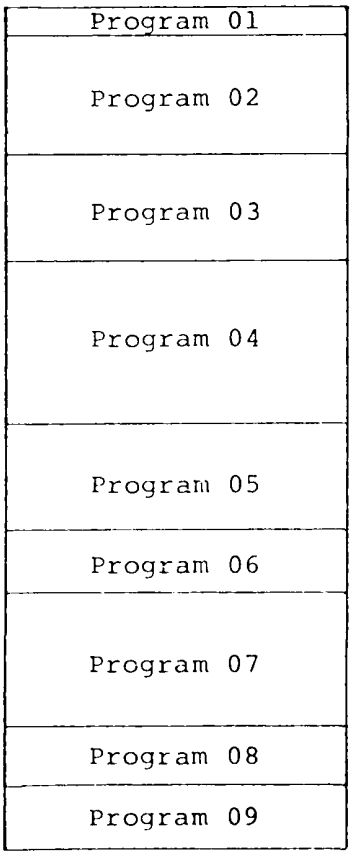
Appendix D is a program that will calculate probability of damage to rectangular, triangular, and elliptical targets.

These auxiliary programs expand the versatility of the basic CROM module by adding interesting features that would otherwise be excluded because of memory constraints and input/output considerations. A control program can reside in calculator memory, and the CROM module is still immediately accessible to the user.



Main Calculator Memory

The boxes to the right are proportional to the sizes of the different memories required in the CROM. Magnetic card programs are read into the main calculator memory illustrated above. A CROM program on the right can be selected and run independently. The data registers, however, are shared by all programs. Any program is able to call a subroutine of another program for execution. Thus a control program residing in the main program memory can call and execute a CROM program as a subroutine.



CROM Program Memory

Operation of the CROM is described in section 1, "General Description." Every code is accessed and run through the universal input routine, program 01, which is also described in section 1. The example problems shown in each section are designed to illustrate the use of the PC-100 printer with the calculator. In cases where intermediate results are printed but not displayed, the storage registers for these results are given so that they may be recalled when using the calculator in the hand-held mode. Storage registers 6-9 and 30-59 are always available to the user and have no effect on CROM program operation.

The inputs necessary to perform the calculations programmed in this CROM are briefly defined in each program section of this document. The user is referred to the Defense Intelligence Agency's Physical Vulnerability Handbook - Nuclear Weapons (U), AP-550-1-2-60-INT, June 1, 1969, CONFIDENTIAL, for further information.

At the top of the first page of every program section of this document is an image titled "AP-550 PROMPT A1". These are images of non-magnetic "prompt" cards that slip into the card holder on the front of the TI-59 calculator. The purpose of these cards is to provide an input guide for the user. No magnetic data is or can be stored on these cards.

Section 1

CROM Operation: General Input Routine and Calculational Capabilities.

AP-550 CROM A1 - GENERAL INPUT ROUTINE AND DESCRIPTION

To facilitate both versatility and ease of use, the DNA/AP-550 CROM A1 was designed to operate entirely through program 01, the universal input routine. To ensure that the AP-550 CROM is installed in the calculator, enter the keystrokes 2nd Pgm 01 SBR 2nd Write. The PC-100 printer will then print:

DNA/AP-550.

Once program 01 has been selected, the calculator can be left in that mode. The universal input program automatically selects all programs and stores all inputs.

Inputs are entered into keys A through E and 2nd A' through 2nd D' in accordance with the input label plan shown in Figure 1. Inputs may be entered in any order, except that in the Equivalent Target Area code, programs 6.0 and 6.1, the length VN and length k-factor must be entered successively into key D, as: length VN, D; length k-factor, D. The same applies to the width VN and k-factor in key E. The offset and radius of safety must also be entered successively into key D when executing program 5.1. Other than these special cases, all inputs can be independently entered before program execution. All inputs are saved (with the exception of environment classification in the Personnel Vulnerability program) during the course of execution and do not need to be re-entered when another calculation is initiated.

To run a calculation, first enter the data with the appropriate keys (as shown in Fig. 1), and then enter a two-digit code number of the form a.b with key 2nd E'. This number selects the primary calculation and subcalculation to be run. All the calculations that may be run, and their associated code numbers, are shown in Table 1. Once a calculation is selected, the code number for that calculation need not be re-entered if a repeat calculation is desired. Pressing R/S will initiate the previous keyed-in calculation even if the inputs are changed.

Programs 2.0 through 2.7

CEP	TARGET RADIUS	OFFSET	DAMAGE SIGMA	
YIELD	HOB		VN	K-FACTOR

Weapon Radius, P and Q Targets; Pd to circular normal targets

Programs 3.0 through 3.2

CEP	TARGET RADIUS	OFFSET	DAMAGE SIGMA	
		WR		

Pd to point and circular targets, normal and uniform dist.

Programs 4.0 and 4.1

YIELD	HOB	ENVIR.		

Personnel Vulnerability

Programs 5.0 through 5.3

TROOP DISP.	VULN.	RISK	DESIRED ASSUR.	
YIELD	HOB	CEP	OFFSET; R.S.	PEH

Minimum Safe Dist., Fallout-Safe HOB

Programs 6.0 and 6.1

CEP	LENGTH	WIDTH	AIM POINT	
YIELD	HOB		LENGTH VN,K	WIDTH VN, K

Prob. of Damage, ETA, VN System

Program 6.2

CEP	LENGTH	WIDTH	AIM POINT	
YIELD	HOB	MEDIUM	LENGTH CRM	WIDTH CRM

Prob. of Damage, ETA, crater radius method

Program 6.3

CEP	LENGTH	WIDTH	AIM POINT	
			LENGTH WR	WIDTH WR

Prob. of Damage, ETA, weapon radius method

Programs 7.0 through 7.4

YIELD	HOB	MEDIUM	RADIUS	

Cratering

Figure 1. An assignment of variables to user-defined keys for each program in AP-550 CROM A1. The lower rows of rectangles for each program type represent Keys A through E. The upper rows represent Keys 2nd A' through 2nd E'.

Table 1. A complete list of calculations available with AP-550 CROM A1.

CODE	DESCRIPTION
2.0	Weapon radius and probability of damage, P-target*
2.1	Weapon radius and probability of damage, Q-target*
2.2	Weapon radius and probability of damage at optimum HOB, P-target*
2.3	Weapon radius and probability of damage at optimum HOB, Q-target*
2.4	Weapon radius, P-target
2.5	Weapon radius, Q-target
2.6	Weapon radius at optimum HOB, P-target
2.7	Weapon radius at optimum HOB, Q-target
3.0	Probability of damage - point target
3.1	Probability of damage - circular normal distribution
3.2	Probability of damage - circular uniform distribution
4.0	Personnel weapon radius, any HOB
4.1	Personnel weapon radius, optimum HOB
5.0	Radius of safety and minimum safe distance
5.1	Probability of not exceeding acceptable weapons effects
5.2	The minimum HOB which has a certain probability of being fallout-safe
5.3	The probability that a certain HOB is fallout-safe
6.0	Probability of damage, ETA, VN method, P-target
6.1	Probability of damage, ETA, VN method, Q-target
6.2	Probability of damage, ETA, crater radius method
6.3	Prob. of damage, ETA, length and width weapon radii specified
7.0	Crater radius, depth and volume
7.1	Invert for HOB
7.2	Invert for yield
7.3	Calculate optimum HOB for maximum crater radius
7.4	Calculate optimum HOB and minimum yield for given crater radius

*circular normal distributions only.

The running calculation prints the calculation code number first, the inputs second, and then pauses until the solution is found and printed. During the input printing cycle, inputs are checked to determine if they are within an acceptable range, if limited by the program. These automatic limits are specified at the end of each program description. If a value falls outside the allowed data range, the calculator sets an error condition, prints the exceeded input, and stops execution with the exceeded limit flashing in the display. The input value itself is in the t-register for inspection. The procedure for correcting the error is to press CLR, re-enter a new input value with the appropriate key, and press R/S to start the calculation over.

Should it become necessary to stop the calculator while a CROM program is running, the reset key, RST, can be pressed to return program control to the keyboard. Pressing the R/S key has no effect when the calculator is running in CROM memory. The RST key also takes the calculator out of any CROM program and leaves the pointer in program 00, which is the program the machine is in when it is turned on or when it is running a magnetic card program. To use the CROM, program 01 must be selected again. For this reason, consider the RST key only as an emergency halt command.

When running the example problems in the following programs, it is useful to note that steps 1 and 2 are always the same: 1) turn off, then on, and 2) select program 01. If the calculator is already on and in program 01, these steps need not be repeated between examples. However, it is important to enter all the inputs required for a particular calculation, otherwise values previously entered will be stored in memory and can be misused. Table 2 lists the inputs and outputs and their corresponding printer alphanumerics for each of the main CROM programs. Note that Table 2 includes the same information presented graphically in Figure 1.

Table 2. Inputs and outputs for each of the main CROM programs and their corresponding printer alphanumerics.

INPUTS	KEY	ALPHA	OUTPUTS	ALPHA
Program 02 (see note at end of table)				
Yield	A	Y	Weapon Radius	W
Height of burst	B	H	Optimum height of burst	H
Vulnerability number	D	V	(printed with inputs)	
k-factor	E	K	Probability of damage	P
Program 03				
Weapon radius	C	W	Probability of Damage	P
Circular error probable	A'	C		
Target radius	B'	T		
Offset	C'	X		
Damage sigma	D'	S		
Program 04				
Yield	A	Y	Weapon radius	W
Height of burst	B	H	Damage sigma	S
Environment	C	E	Optimum height of burst (printed with inputs)	H
Program 05				
Yield	A	Y	Radius of safety	RS
Height of burst	B	H	Minimum safe distance	M
Circular error probable	C	C	Probability	P
Offset	D	X	Height of burst	H
Radius of safety	E	RS		
Probable error in height	F	PH		
Type dispersion	A'	D		
Vulnerability condition	B'	V		
Acceptable risk	C'	R		
Desired probability	D'	P		
Program 06				
Yield	A	Y	Length weapon radius	LW
Height of burst	B	H	Width weapon radius	WW
Length VN	D	LV		
Width VN	E	WV		
Length k-factor	D	LK		
Width k-factor	E	WK		
Circular error probable	A'	C		
Length	B'	L		
Width	C'	W		
Aim point	D'	A		
Soil medium	C	M		

Table 2. (Continued)

INPUTS	KEY	ALPHA	OUTPUTS	ALPHA
Program 06 (continued)				
Length crater radius multiplier	D	LM		
Width crater radius multiplier	E	WM		
Length weapon radius	D	LW		
Width weapon radius	E	WW		
Program 07				
Yield	A	Y	Radius	R
Height of burst	B	H	Depth	D
Soil Medium	C	M	Volume*	none
Radius	D	R	Yield (also minimum yield)	Y
			Height of burst (also optimum height of burst)	H

* Volume will appear in the display after pressing 2nd x.

Note on Program 02: Programs 2.0 through 2.3 calculate probability of damage to circular normal targets in addition to weapon radii. This is made possible by an internal command that automatically transfers the calculated weapon radii to program 03. Therefore, to calculate a probability of damage utilizing program 02., i.e., to invoke calculations 2.0 through 2.3, the inputs listed for program 03 must also be entered with the exception of weapon radius.

The appendices to this document contain magnetic card auxiliary programs that use the CROM module's programs as subroutines. The auxiliary programs are designed to enhance the CROM's versatility by providing inversion routines for the CROM's main program, iteration routines for parameter studies and special case considerations. A list of calculations possible when the auxiliary program magnetic cards are used in conjunction with the AP-550 CROM AI is given in Table 3.

Table 3. A list of auxiliary magnetic card programs given in the appendices of this document.

CONTROL CARD CALCULATIONS

Appendix A - Demonstration Program

(a) will run a number of CROM programs in a single execution, with parameters defaulting to programmed values. Inputs can be changed at the option of the user.

Appendix B - Iterations

(a) Appendix B1 will increment up to five different inputs through a specified range to perform large numbers of calculations in a single execution.

(b) Appendix B2 is similar to Appendix B1, except that the values of the input parameter being changed are explicitly specified.

Appendix C - Inversions

(a) Appendix C1 inverts the VNTK System for yield.

(b) Appendix C2 inverts the Personnel vulnerability code for yield.

(c) Appendix C3 inverts the Cratering code for the deeper depth of burst.

Appendix D - Probability of Damage

(a) Will calculate probability of damage to rectangular, elliptical and triangular targets by the method shown in AP-550.

PARTITION	FLAG	COMMENTS	FLAG	COMMENTS
AUTOMATIC	07	exceeded limit flag (reset in this program, set by called programs)		

LIBRARY MODULE: CROM A-1 (Program 1)

DATA REGISTERS FOR EXAMPLE _____

DATA	REG.	COMMENTS	LABELS STEP	CODE	KEY	COMMENTS
		Program in use	001	14	D	→R13, R19
		Line for SBR call	003	14	7	formatting
		Reg. no. for input in use	030	15	E	→R14, R20
			035		D	→R10
			037		D	→R11
			042		D	→R12
		used by called program	044		A'	→R15
			054		B'	→R16
			061		C'	→R17
			066		D'	→R18
		Input, key A	071		E	advance paper
		Input, key B	073		E'	initiate calc
		Input, key C	152		E	header
		Last input, key D				
		Last input, key E				
		Input, key A'				
		Input, key B'				
		Input, key C'				
		Input, key D'				
		Next to last input, key D				
		Next to last input, key E				
		Used by called program				

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
000	76	LBL	If one input: Input → R13
001	14	D	
002	43	EXC	D
003	13	13	
004	42	STO	If two inputs: 1st input → R19 2nd input → R13
005	19	19	
006	43	RCL	
007	13	13	
008	76	LBL	
009	34	ΓX	
010	58	FIX	
011	09	09	
012	22	INV	
013	57	ENG	
014	32	RTN	
015	43	RCL	Initiate calculation on R/S
016	00	00	
017	61	GTO	
018	10	E'	
019	76	LBL	If one input: Input → R14
020	15	E	
021	43	EXC	E
022	14	14	
023	42	STO	If two inputs: 1st input → R20 2nd input → R14
024	20	20	
025	43	RCL	
026	14	14	
027	61	GTO	
028	34	ΓX	
029	76	LBL	
030	11	A	Input → R10
031	42	STO	A
032	10	10	
033	61	GTO	
034	34	ΓX	
035	76	LBL	
036	12	B	Input → R11
037	42	STO	B
038	11	11	
039	61	GTO	
040	34	ΓX	
041	76	LBL	
042	13	C	Input → R12
043	42	STO	C
044	12	12	
045	61	GTO	
046	34	ΓX	

STEP	CODE	KEY	COMMENTS
047	76	LBL	A' Input → R15
048	16	A'	
049	42	STO	
050	15	15	
051	61	GTO	
052	34	ΓX	
053	76	LBL	B' Input → R16
054	17	B'	
055	42	STO	
056	16	16	
057	61	GTO	
058	34	ΓX	
059	76	LBL	C' Input → R17
060	18	C'	
061	42	STO	
062	17	17	
063	61	GTO	
064	34	ΓX	
065	76	LBL	D' Input → R18
066	19	D'	
067	42	STO	
068	18	18	
069	61	GTO	
070	34	ΓX	
071	76	LBL	Return after calculation
072	31	R/S	
073	38	ADV	
074	38	ADV	
075	38	ADV	
076	32	RTN	
077	43	RCL	Same calculation R/S
078	00	00	
079	76	LBL	Label E'. Initiate CROM calc. (Pgm)
080	10	E'	
081	42	STO	
082	00	00	
083	35	CLR	
084	32	RTN	
085	35	CLR	
086	01	1	
087	00	0	
088	42	STO	Used to recall input values with RCL IND 02
089	02	02	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
094	65	×	
095	43	RCL	
096	00	00	
097	89	PRT	
098	22	INV	For directing pointer to proper label
099	28	INT	
100	85	+	
101	33	X↑T	
102	04	4	
103	22	INV	If frac(R00) > .4 (P-target)
104	17	GE	
105	01	01	
106	18	18	
107	65	×	
108	32	X↑T	
109	85	+	
110	01	1	
111	02	2	
112	07	7	
113	55	=	
114	42	STO	
115	21	01	
116	83	GO+	Will go to appropriate subroutine call
117	21	01	
118	02	2	Re-adjust program pointer when frac(R00) > .4
119	00	0	
120	54	+/-	
121	82	HIR	
122	31	31	
123	04	4	
124	61	GTO	
125	01	01	
126	07	07	
127	82	PG+	x.0
128	00	00	
129	11	A	
130	61	GTO	
131	91	R/S	
132	82	PG+	x.1, x.5
133	00	00	
134	12	B	
135	61	GTO	
136	91	R/S	
137	82	PG+	x.2, x.6
138	00	00	
139	13	C	
140	61	GTO	

STEP	CODE	KEY	COMMENTS
141	91	R/S	
142	82	PG+	x.3, x.7
143	00	00	
144	14	D	
145	61	GTO	
146	91	R/S	
147	82	PG+	x.4, x.8
148	00	00	
149	71	SBR	
150	76	PAU	
151	61	GTO	
152	91	R/S	
153	76	LBL	Label WRITE: HEADER (identify CROM)
154	36	WRT	
155	99	DP	Print:
156	00	00	
157	98	ADV	
158	01	1	
159	06	6	
160	03	3	
161	01	1	"DNA/AP-550"
162	01	1	
163	03	3	
164	06	6	
165	03	3	
166	01	1	
167	03	3	
168	99	DP	
169	02	02	
170	02	2	
171	03	3	
172	02	2	
173	00	0	
174	00	0	
175	05	5	
176	00	0	
177	06	6	
178	00	0	
179	01	1	
180	99	DP	
181	03	03	
182	99	DP	
183	05	05	
184	98	ADV	
185	98	ADV	
186	98	ADV	
187	25	CLR	
188	92	RTN	

PARTITION	FLAG	COMMENTS	FLAG	COMMENTS
AUTOMATIC	00	Prevents limit checks from halting on error	09	Used in other programs; reset in case of error to turn off trace mode
LIBRARY MODULE: CROM A-1 (Program 9)	01	Suppresses printing		
	07	Set if limit exceeded		

DATA REGISTERS FOR EXAMPLE _____

DATA	REG.	COMMENTS
	00	
	01	
	02	
	03	Register number for input in use
	04	
	05	
	06	
	07	
	08	
	09	
	10	Used by PGM 7 segment
	11	Used by PGM 7 segment
	12	Used by PGM 7 segment
	13	
	14	
	15	
	16	
	17	
	18	Used by PGM 7 segment
	19	
	20	
	21	
	22	
	23	
	24	
	25	
	26	
	27	
	28	
	29	
	30	
	31	
	32	Used by PGM 7 segment
	33	
	34	
	35	
	36	
	37	
	38	
	39	
	40	

LABELS STEP	CODE	KEY	COMMENTS
001	12	B	Round and print outputs
015	17	B'	
024	13	C	Check and print inputs
032	11	A	
059	16	A'	
075	18	C'	
109	15	E	Overflow from PGM 7

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
000	76	LBL	Label B. Rounds argument to 3 significant digits and prints (outputs)
001	12	B	
002	53	EE	
003	53	FIX	
004	02	02	
005	53	EE	
006	53	FIX	
007	09	09	
008	85	+	
009	32	X↔T	
010	22	INV	
011	53	EE	
012	61	GTO	
013	11	A	
014	76	LBL	Label B'. Takes lower limit for Y in display and checks and prints Y (if R02=10)
015	12	B'	
016	85	+	
017	04	4	
018	05	5	
019	32	X↔T	
020	03	3	
021	53	EE	
022	04	4	
023	76	LBL	Label C.
024	13	C	
025	65	×	Checks limits on RC*2 (used in sequential inputs)
026	73	RC*	
027	02	02	
028	69	OP	
029	22	22	
030	32	X↔T	
031	76	LBL	Label A. Check limits on input, entered with: input, x ↔ t, x_0 + hi x alpha
032	11	A	
033	69	OP	
034	04	04	
035	35	CLR	
036	82	HIR	
037	11	11	
038	67	EQ	
039	00	00	If x = x_0 then skip rest of checks
040	50	50	
041	77	GE	
042	00	00	
043	86	86	Error routine if x<x_0
044	82	HIR	
045	12	12	
046	22	INV	
047	77	GE	
048	00	00	Error routine if x > hi
049	86	86	
050	32	X↔T	
051	87	IFF	
052	01	01	Printing suppressed if flag 1 set
053	00	00	
054	57	57	
055	69	OP	
056	06	06	
057	92	RTN	
058	76	LBL	Label A'. Integerize RC*2 (as input), check limits and print. Entered by the sequence: alpha x ↔ t hi
059	14	A'	
060	82	HIR	
061	02	02	
062	01	1	
063	95	+	
064	73	RC*	
065	02	02	
066	59	INT	
067	72	ST*	
068	02	02	
069	69	OP	
070	22	22	
071	32	X↔T	
072	61	GTO	
073	11	A	
074	76	LBL	Label C'. Replaces input RC*2 by its absolute value and prints. (lower limit implicitly 0). Entered with alphanumeric in display.
075	13	C'	
076	32	X↔T	
077	73	RC*	
078	02	02	
079	50	I×I	
080	72	ST*	
081	02	02	
082	85	+	
083	61	GTO	
084	00	00	
085	28	28	
086	98	ADV	Error handling:
087	69	OP	
088	88	88	Set error
089	71	SBR	
090	00	00	
091	50	50	Print with error
092	22	INV	
093	86	STF	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
094	09	09	
095	32	INV	
096	37	IFF	Stop on error unless
097	00	00	flag 0 is set
098	01	01	
099	05	05	
100	36	STF	
101	00	00	Error has occurred
102	36	STF	
103	01	01	Suppress further
104	32	RTN	printing
105	32	INV	
106	42	STO	
107	25	CLR	(nonexistent label)
108	16	LBL	Label E is called from
109	15	E	program 4, step 869
110	55	÷	
111	04	4	
112	05	5	b
113	43	RCL	
114	12	12	Environment
115	32	INV	
116	43	RCL	
117	10	10	Y
118	55	÷	
119	44	+/-	
120	45	Y^x	
121	53	(	
122	01	1	
123	03	3	
124	00	0	
125	02	2	More packed data,
126	00	0	class 19
127	04	4	
128	42	STO	
129	13	13	
130	01	1	
131	09	9	
132	07	E0	
133	01	01	
134	56	56	
135	55	÷	Eq. 29, Pgm. 4
136	01	1	
137	03	3	
138	03	3	
139	33	x²	
140	03	3	

STEP	CODE	KEY	COMMENTS
141	65	×	
142	01	1	
143	04	4	
144	00	0	More packed data,
145	02	2	class 20
146	00	0	
147	03	3	
148	07	7	
149	42	STO	
150	13	13	
151	01	1	
152	01	1	Data for class 19,
153	00	0	Eq. 27
154	00	0	
155	83	.	
156	06	6	Data for class 20,
157	06	6	Eq. 27
158	07	7	
159	32	INV	
160	83	.	
161	04	4	Eq. 29, Pgm. 4
162	04	4	
163	05	5	
164	94	+/-	
165	85	+	(Y-b)^P
166	55	÷	
167	01	1	
168	52	EE	Compensates for 10^3
169	03	3	
170	65	×	
171	53	(	
172	43	RCL	Eq. 27, Pgm 4
173	23	23	
174	65	×	
175	93	.	
176	01	1	
177	49	PRD	
178	02	02	2-digit coefficient
179	55	÷	
180	43	RCL	
181	12	12	
182	42	STO	
183	19	19	Environment
184	32	INV	1100,667 or 667
185	85	+	
186	32	RTN	
187	04	4	Radius and depth coeffs, Pgm. 7

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
188	04	4	h Equation 5 - Dry Rock Coeff.
189	07	7	
190	01	1	
191	08	8	g
192	04	4	
193	07	7	
194	04	4	f
195	02	2	
196	42	STO	
197	21	21	
198	01	1	d Equation 4 coeff.
199	06	6	
200	00	0	c
201	02	2	
202	03	3	
203	07	7	b
204	00	0	
205	01	1	
206	05	5	a
207	00	0	
208	32	RTN	
209	04	4	Equation 5 -
210	06	6	h Wet Rock
211	07	7	
212	01	1	g
213	07	7	
214	03	3	
215	07	7	f
216	01	1	
217	06	6	
218	42	STO	
219	21	21	
220	05	5	Equation 4
221	01	1	c
222	05	5	
223	03	3	
224	06	6	b
225	00	0	
226	01	1	
227	05	5	a
228	02	2	
229	32	RTN	
230	01	1	j Equation 5
231	05	5	Dry Soil and Wet Soil
232	06	6	
233	08	8	
234	01	1	h

STEP	CODE	KEY	COMMENTS
235	03	3	g
236	00	0	
237	05	5	
238	06	6	f
239	00	0	
240	42	STO	
241	21	21	
242	05	5	Equation 4
243	00	0	c Dry Soil
244	07	7	
245	02	2	
246	05	5	b
247	00	0	
248	01	1	
249	01	1	a
250	07	7	
251	32	RTN	
252	43	HOF	Equation 5 Wet Soil
253	71	SBR	
254	02	02	
255	30	30	
256	03	3	d Equation 4
257	08	8	
258	03	3	c
259	05	5	
260	02	2	
261	09	9	b
262	00	0	
263	01	1	
264	02	2	
265	08	8	a
266	85	+	
267	93	.	
268	03	3	
269	95	=	
270	92	RTN	
271	02	2	n Equation 3 - Wet Soil
272	07	7	
273	03	3	p
274	03	3	
275	00	0	m
276	08	8	
277	42	STO	
278	21	21	k = 11
279	71	SBR	
280	02	02	
281	99	99	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
282	04	4	Equation 2
283	03	3	s
284	04	4	t
285	05	5	
286	02	2	q
287	03	3	
288	93	.	
289	07	7	
290	92	RTN	
291	05	5	n Equation 3
292	01	1	Dry Soil
293	07	7	
294	03	3	p
295	02	2	
296	05	5	m
297	42	STO	
298	21	21	
299	01	1	k
300	01	1	
301	42	STO	
302	22	22	
303	06	6	s Equation 2
304	09	9	
305	09	9	t
306	04	4	
307	03	3	q
308	08	8	
309	92	RTN	
310	00	NOP	n Equation 3
311	02	2	Wet Rock
312	01	1	
313	01	1	p
314	05	5	
315	00	0	m
316	08	8	
317	42	STO	
318	21	21	
319	07	7	
320	93	.	k
321	05	5	
322	42	STO	
323	22	22	
324	03	3	s Equation 2
325	08	8	
326	02	2	t
327	07	7	
328	02	2	q

STEP	CODE	KEY	COMMENTS
329	07	7	
330	92	RTN	
331	03	3	Equation 3
332	09	9	n Dry Rock
333	02	2	
334	05	5	p
335	04	4	
336	00	0	m
337	42	STO	
338	21	21	
339	05	5	
340	93	.	k
341	05	5	
342	42	STO	
343	22	22	
344	03	3	s Equation 2
345	06	6	
346	01	1	t
347	05	5	
348	03	3	
349	04	4	q
350	93	.	
351	02	2	
352	92	RTN	
353	06	6	HOB COEFFICIENTS
354	04	4	
355	02	2	Wet
356	06	6	Soil
357	05	5	
358	03	3	
359	05	5	
360	92	RTN	
361	02	2	
362	04	4	
363	08	8	Dry
364	04	4	Soil
365	09	9	
366	03	3	
367	05	5	
368	92	RTN	
369	01	1	
370	04	4	
371	00	0	Wet
372	05	5	Rock
373	03	3	
374	03	3	
375	02	2	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS	STEP	CODE	KEY	COMMENTS
376	92	RTN					
377	03	3	γ				
378	03	3	Dry				
379	04	4	β Rock				
380	06	6					
381	02	2					
382	03	8	α				
383	92	RTN					
384	01	1	YIELD				
385	06	6	COEFFICIENTS				
386	04	4					
387	00	0	w Dry				
388	05	5	Rock				
389	92	RTN					
390	01	1	z				
391	09	9	Wet				
392	04	4	Rock				
393	02	2	w				
394	05	5					
395	92	RTN					
396	01	1	z				
397	09	9	Dry				
398	04	4	Soil				
399	06	6	x				
400	08	8					
401	92	RTN					
402	02	2	z				
403	05	5	Wet				
404	04	4	Soil				
405	04	4	w				
406	02	2					
407	92	RTN					

Section 2: Programs 2.0 - 2.7

Weapon Radius Determination for P-type and Q-type Targets.
Probability of Damage to Point and Circular Targets With
Normal Target Element Distributions.

DNA	AP-550 PROMPT AI			HTI
WEAPON RADIUS, P and Q TARGETS; Pd to CIRCULAR TARGETS (NORM)				
CEP (ft)	TARGET RADIUS (ft)	OFFSET (ft)	DAMAGE SIGMA	2.n - WR,Pd
YIELD (KT)	HOB (ft)		VN	K-FACTOR

SOURCE OF DATA:

Defense Intelligence Agency, Physical Vulnerability Handbook-Nuclear Weapons (U), AP-550-1-2-60-INT, June 1, 1969, Part I, Section B; Part IV, Section A.

DESCRIPTION:

A. Objective

The main objective of this set of eight programs is to calculate weapon radii, (WR), utilizing the VNTK system. Four of the programs provide an option that enables the user to calculate the probability of damage, (Pd), to point targets or to circular area targets with normal target element distributions, using the previously calculated weapon radius. This option is essentially an internal transfer by the calculator to program set 03 and therefore the user is referred to the program 03 documentation for details concerning the probability of damage calculations.

The calculated weapon radius, as defined in AP-550, is: "a circle centered at ground zero, within which, on the average, there are as many targets damaged to a lesser degree than specified as there are targets damaged to the specified degree outside the circle." A more precise definition relates weapon radius to the radius of damage at which there is a 50% probability (RD_{50}) of achieving the desired damage; $WR=RD_{50}/(1-\sigma_d^2)$, where σ_d is the damage sigma. The P-type target weapon radius calculation assumes a damage sigma of 0.2 and the Q-type target weapon radius calculation assumes a damage sigma of 0.3. The user is cautioned that when performing the optional probability of damage calculation, the appropriate damage sigma must be entered to obtain valid results.

B. Inputs-Outputs

The eight calculations comprising this program set and their necessary inputs are as follows:

Program 2.0: WR and Pd - P-type targets,

Inputs:		
	Yield (KT)	CEP (ft)
	HOB (ft)	Target radius (ft)
	VN	Offset (ft)
	k-factor	Damage sigma, σ_d = 0.2 for P-type targets

Program 2.1: WR and Pd - Q-type targets,

Inputs: Same as program 2.0 with the exception that σ_d=0.3

Program 2.2: WR and Pd at optimum HOB - P-type targets,

Inputs: Same as program 2.0 with the exception that no HOB is entered, σ_d = 0.2

Program 2.3: WR and Pd at optimum HOB - Q-type targets,

Inputs: Same as program 2.2 with the exception σ_d= 0.3

Program 2.4: WR - P-type targets,

Inputs:		
	Yield (KT)	VN
	HOB (ft)	k-factor

Program 2.5: WR - Q-type targets,

Inputs: Same as program 2.4

Program 2.6: WR at optimum HOB - P-type targets,

Inputs: Same as program 2.4 with the exception of HOB.

Program 2.7: WR at optimum HOB - Q-type targets,

Inputs: Same as program 2.4 with the exception of HOB.

C. Limits

Yield: $0.1 \text{ KT} \leq Y \leq 30 \text{ MT}$

HOB: $0 \text{ ft} \leq \text{HOB}/Y^{1/3} \leq \text{HOB}_{max}$

where:

$\text{HOB}_{max} = 2308\ Y^{1/3} \exp(-AJVN/15)$ for P-targets

HOB_{max} = the minimum of:

$$\left.\begin{array}{l} 900Y^{1/3} \\ 2308Y^{1/3} \exp(-AJVN/15) \end{array}\right\} \text{Q-targets}$$

where AJVN = adjusted vulnerability number.

VN:	$0 \leq AJVN \leq 54$, P-target
	$0 \leq AJVN \leq 34$, Q-target
k-factor:	$0 \leq k \leq 9$
CEP:	CEP ≥ 0 ft.
Target Radius (TR):	TR ≥ 0 ft.
Offset (x):	$x \geq 0$ ft.
Damage sigma (σ):	$0.1 \leq \sigma \leq 0.5$

D. Data Storage Locations and Printer Alphanumerics

The user can find the following information stored in the indicated registers (R):

Variables	Registers	Alphanumerics
Yield (KT)	R10	Y
HOB (ft)	R11	H
VN	R13	V
k-factor	R14	K
CEP (ft)	R15	C
Target Radius (ft)	R16	T
Offset (ft)	R17	X
Damage Sigma	R18	S
Weapon radius	R12	W
Prob. of Damage	only in display	P

E. Additional Information

Information pertaining to the target VNTK descriptions and damage sigmas can be found in the classified version of this document and AP-550.

Pressing R/S will initiate the previously keyed-in type of calculation even if the inputs are changed.

EXAMPLE 2.0, 2.1, 2.3

Given the following information, calculate the weapon radius and corresponding probability of damage to an area target with a normal target element distribution.

target type	= P-type	damage sigma	= 0.2
VN number	= 15	offset	= 500 ft
k-factor	= 3	CEP	= 200 ft
Yield	= 100 KT	target radius	= 10,000 ft
HOB	= 4000 ft		

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
1	Turn off, then on			0	
2	Select program 01		2nd Pgm 01	0.	
3	Enter yield (KT)	100	A	100.	
4	Enter HOB (ft)	4000	B	4000.	
5	Enter VN	15	D	15.	
6	Enter k-factor	3	E	3.	
7	Enter CEP (ft)	200	2nd A'	200.	
8	Enter target radius (ft)	10000	2nd B'	10000.	
9	Enter offset (ft)	500	2nd C'	500.	
10	Enter damage sigma	.2	2nd D'	0.2	
11	Calc. WR and Pd - P-type	2.0	2nd E'		2.
					100. Y
					15. V
					3. K
					4000. H
					3870. W
					200. C
					10000. T
					500. X
					0.2 S
				0.341	0.341 P

EXAMPLE 2.0, 2.1, 2.3 (cont.)

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
12	Perform same calculation for Q-type target with same VN and k-factor.				
13	Enter Q-type target damage sigma	.3	2nd D'	0.3	
14	Begin calculation	2.1	2nd E'		2.1 100. Y 15. V 3. K 4000. H 3550. W 200. C 10000. T 500. X 0.3 S 0.283 P
15	Repeat calculation described in Step 12 for the optimum HOB case	2.3	2nd E'		2.3 100. Y 15. V 3. K
16	Note optimum HOB = 2220 ft.				2220. H 4650. W 200. C 10000. T 500. X 0.3 S 0.43 P

EXAMPLE 2.4, 2.5:

Given the following information, calculate the weapon radius for the given HOB.

target type = P-type
VN = 6
k-factor = 0
yield = 1.0 KT
HOB = 400 ft

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
1	Turn off, then on			0	
2	Select program 01		2nd Pgm 01	0.	
3	Enter yield (KT)	1	A	1.	
4	Enter HOB (ft)	400	B	400.	
5	Enter VN	6	D	6.	
6	Enter k-factor	0	E	0.	
7	Calc. WR - P-type	2.4	2nd E'		2.4 1. Y 6. V 0. K 400. H
				2480.	2480. W
8	Perform same calculation for Q-type target with same VN & K.				
9	Enter Q-type target damage sigma	.3	2nd D'	0.3	
10	Begin calculation	2.5	2nd E'		2.5 1. Y 6. V 0. K 400. H
				2580.	2580. W

EQUATIONS

Definitions

Y = Yield (KT)

HOB = Height of burst (ft)

VN = Vulnerability number

K = K-factor

$\hat{H}$ = scaled HOB = $HOB/Y^{1/3}$

x_0 = scaled optimum HOB

WR = Weapon radius

$\hat{WR}$ = Scaled weapon radius

x' = Scaled HOB at which $\hat{WR}=1$

AV = Adjusted VN (ADJVN)

Calculation of AV:

$$AV = VN + C\ell nR \tag{1}$$

where for P-targets,

$$C = 11$$

$$R = \frac{1}{2}\left(\frac{K}{10}\right)\left(\frac{20}{Y}\right)^{1/3} + \sqrt{\left[\frac{1}{2}\left(\frac{K}{10}\right)\left(\frac{20}{Y}\right)^{1/3}\right]^2 + \left(1 - \frac{K}{10}\right)}, \tag{2}$$

and for Q-targets,

$$C = 8.2$$

R satisfies the equation, $R^3 - \frac{K}{10}\left(\frac{20}{Y}\right)^{1/3} R + \frac{K}{10} - 1 = 0$, (3)

which is solved iteratively.

The quantity $20^{1/3} = 2.7144...$ is approximated with $e = 2.718...$

For both P and Q targets,

$$WR = \left(\frac{\hat{WR}-2 + |\hat{WR}-2|}{2}\right) Y^{1/3} \quad \text{(presents WR < 2 as WR = 0)} \tag{4}$$

P-target equations:

$$\hat{WR} = \alpha\left(1 + a\left(\frac{\hat{H}}{x_0}\right)^P\right), \text{ for } \hat{H} \leq x_0 \tag{5}$$

$$= \alpha\left(1 + a\left(\frac{\hat{H}}{x_0}\right)^P\right)\exp\left[-\ell n(\alpha(1+a))\left(\frac{(\hat{H}/x_0)-1}{(x'/x_0)-1}\right)^\gamma\right] \text{ for } \hat{H} > x_0 \tag{5'}$$

where:

$$\alpha = \exp\left(7.63 - \frac{AV}{6}\right) + \exp\ 7.37 - \frac{AV}{16} \tag{6}$$

$$a = \frac{(26-AV)^4}{1890 + 31(26-AV)^3}\ ,\ \text{for } AV \leq 26 \tag{7}$$

$$= \frac{(AV-26)}{160}\ ,\ \text{for } AV > 26 \tag{8}$$

$$P = .6 + \exp[-(.393AV - 9.5\ell n(.393AV) + 3.3^2)] \tag{9}$$

$$x_0 = \exp(6 + \sqrt{2} - AV/15.7) \tag{10}$$

$$x' = 4.5 \times 10^9/(26 + AV)^4 \tag{11}$$

$$\gamma = \exp(.1 + AV/37) \tag{12}$$

Q-target equations:

$$\hat{WR} = \alpha\left(1 + a\left(\frac{\hat{H}}{x_0}\right)^P\right)\ ,\ \hat{H} \leq x_0 \tag{13}$$

$$= \alpha\left(1 + a\left(\frac{\hat{H}}{x_0}\right)^P\right) \exp\left[b\left(1 - \frac{\hat{H}}{x_0}\right)\right]\ ,\ \hat{H} > x_0 \tag{14}$$

where:

$$\alpha = [\exp(133 - 1.82\ AV) + \exp(128 - 1.4\ AV)]^{\frac{1}{16}} \tag{15}$$

$$\alpha(a+1) = [\exp(158 - 1.4\ AV) + \exp(177 - 2.7\ AV)]^{\frac{1}{20}} \tag{16}$$

$$P = \left[1 + (AV/33)^8\right]^{-1} \tag{17}$$

$$x_0 = [\exp(-.24^2\ AV)]^{\frac{1}{2}} \left\{960 - 410\left[\frac{\exp(.27AV^{1.2} - 6.5)}{1+\exp(.27AV^{1.2}-6.5)}\right]\right\} \tag{18}$$

$$b = .03AV + 4.6(9 + (AV-24)^2)^{-1} \tag{19}$$

PARTITION

AUTOMATIC

LIBRARY MODULE

CROM A-1 (Program 2)

FLAG	COMMENTS	FLAG	COMMENTS
07	test for limit check error		
09	set - P target not set - Q target		

DATA REGISTERS FOR EXAMPLE 2.0

DATA	REG.	COMMENTS
2.	00	# of Pgm originally called
.8045060006	01	scratch
19.	02	
4810.405388	03	
500.	04	scaled WR
.1802558265	05	scratch
0.	06	not used
0.	07	
0.	08	
0.	09	
100.	10	Y
4000.	11	HOB, Opt. HOB
3870.	12	Scratch; calculated WR
15.	13	VN
3.	14	k
300.	15	CEP
10000.	16	Target radius
500.	17	Offset
0.2	18	Damage sigma
0.	19	not used
1.210358997	20	
-.8045060006	21	AJVN
-.9107730409	22	
16.2454832	23	
.0003541857	24	
.5487635763	25	
-.4592145161	26	
-.5643088943	27	

LABELS

STEP	CODE	KEY	COMMENTS
001	15	E	common code
012	10	E'	
020	13	C'	choose coeff.
026	18	NOP	
029	16	A'	calculate α
056	17	B'	calculate W_{max}
082	19	D'	calculate x_0
106	24	+ -	adjust VN
197	4	D	Q target opt.H
200	13	C	P target opt.H
260	12	B	Q target
263	16	PAU	P target
265	11	A	
285	09	n	main calc.

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
000	76	LBL	Label E.
001	15	E	Common to subroutines
002	34	X	A' and B'
003	43	RCL	AJVN
004	21	21	
005	54	×	
006	42	INV	
007	43	LNX	
008	55	÷	
009	43	(	
010	02	RTN	
011	76	LBL	Label E'.
012	11	E'	Common to subroutines
013	15	E	A' and B'
014	00	0	
015	85	=	
016	42	INV	
017	34	X⇄	
018	43	RTN	
019	76	LBL	Label C'.
020	13	C'	Select coefficient for
021	03	IFF	P- or Q-target
022	09	09	
023	03	NOP	
024	34	X⇄T	
025	76	LBL	Label NOP
026	03	NOP	
027	43	RTN	
028	76	LBL	Label A'.
029	10	A'	
030	03	IFF	Calculates α
031	09	09	
032	04	04	
033	86	STF	·P-target calc.
034	01	1	
035	03	3	
036	03	3	
037	05	5	
038	01	1	
039	03	3	
040	08	8	
041	02	2	
042	15	E	
043	01	1	
044	02	2	
045	08	8	
046	55	÷	
047	01	1	
048	03	3	
049	04	4	
050	10	E'	
051	01	1	
052	00	0	
053	85	=	α for Q target (eq. 15)
054	43	RTN	
055	76	LBL	Label B'.
056	11	B'	
057	03	IFF	Calculates $\alpha(a+1)=\hat{W}$ max
058	09	09	
059	04	04	·P-target calculation
060	86	STF	
061	01	1	
062	05	5	
063	08	8	
064	55	÷	
065	01	1	
066	00	0	
067	04	4	
068	00	0	
069	01	1	
070	03	3	
071	04	4	
072	03	3	
073	05	5	
074	01	1	
075	03	3	
076	08	8	
077	02	2	
078	15	E	
079	01	1	
080	02	2	$\hat{W}$ max for Q target (eq. 16)
081	76	LBL	Label D'.
082	12	D'	
083	43	RCL	Calculates x_0=optimum H
084	21	21	
085	44	+	
086	42	INV	
087	03	IFF	
088	09	09	
089	05	05	
090	03	03	
091	55	÷	
092	01	1	
093	05	5	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
094	43	.	
095	04	4	
096	55	÷	
097	01	1	
098	14	14	
099	55	÷	
100	02	2	
101	85	=	
102	22	INV	
103	23	LNX	x_0 for P target (Eq.10)
104	83	RTN	
105	76	LBL	Label +/-
106	84	+/-	
107	65	×	
108	01	1	
109	00	0	Check and print VN, K;
110	00	0	calculate AJVN → R_{21},
111	95	+	HOB limits
112	04	4	
113	02	2	
114	85	=	
115	42	STO	
116	01	01	Alphanumeric
117	43	RCL	
118	14	14	K Calculate VN
119	55	÷	adjustment factor
120	01	1	
121	00	0	
122	65	×	
123	42	STO	
124	04	04	
125	69	OP	
126	34	34	R04 ← $\frac{K}{10} - 1$
127	53	(	
128	43	RCL	
129	10	10	Y
130	22	INV	
131	45	YX	
132	03	3	
133	84	+/-	
134	54	)	
135	42	STO	Stores $Y^{-1/3}$ in R03
136	03	03	
137	01	1	
138	22	INV	
139	23	LNX	
140	95	=	

STEP	CODE	KEY	COMMENTS
141	42	STO	R05 ← $\frac{K}{10} e^{Y^{1/3}}$
142	05	05	
143	55	÷	
144	02	2	
145	85	=	
146	69	OP	
147	05	05	→P target calc.
148	00	00	
149	85	=	Calculate R for AJVN,
150	04	4/-	Q target
151	85	+	(Eq. 3)
152	43	.	
153	00	0	
154	00	0	
155	05	5	ε = .005 allowed error
156	03	x≥t	
157	01	1	
158	85	=	
159	42	STO	Estimate for R → R21
160	21	21	
161	65	×	Iteration loop
162	53	(	
163	43	RCL	
164	85	-	
165	43	RCL	$\frac{K}{10} e^{Y^{-1/3}}$
166	05	05	
167	54	)	
168	95	+	
169	43	RCL	$\frac{K}{10} - 1$
170	14	14	
171	85	=	
172	65	×	
173	53	(	
174	43	RCL	
175	11	11	
176	55	÷	
177	53	(	
178	53	(	
179	43	RCL	
180	21	21	Estimate for R
181	65	×	
182	43	RCL	
183	03	03	
184	54	)	
185	42	STO	$\frac{K}{10} e^{Y^{-1/3}}$
186	05	05	
187	85	=	

Jump to rest of calculations

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
188	22	INV	
189	44	SUM	
190	11	A	
191	43	RCL	
192	11	A	Improved R
193	91	GTO	
194	01	01	
195	01	A	
196	76	LBL	Label D.
197	14	D	
198	42	STO	Q target, opt. H
199	08	08	
200	76	LBL	Label C.
201	12	B	
202	42	STO	P target, opt. H
203	09	09	
204	98	R/S	
205	05	05	Check and print Y, VN, K
206	91	R/S	
207	43	RCL	Return without calculating WR if limit error occurred.
208	09	09	
209	42	STO	
210	00	00	
211	98	RTN	
212	02	02	
213	76	LBL	
214	16	A'	Calculate $\hat{\epsilon}$ (needed for P target $\hat{W}$ max)
215	42	STO	
216	12	12	
217	14	D'	Calculate $\hat{H}$ opt. = x_0
218	42	STO	
219	04	04	
220	44	SUM	$Y^{-1/3}$ is in R_{03} from SBR +/-
221	11	A	
222	43	RCL	
223	03	03	
224	36	PGM	Print optimum H
225	02	02	
226	43	RCL	
227	00	00	
228	91	R/S	
229	15	E'	Calculate $\hat{W}$ max
230	55	÷	
231	02	2	
232	65	×	Make W max = 2 · 0 (Eq. 4)
233	11	1	
234	85	+	

STEP	CODE	KEY	COMMENTS
235	50	I×I	
236	85	+	
237	42	STO	Modified W
238	04	04	
239	43	RCL	t register = WR
240	22	INV	
241	86	STF	
242	09	09	
243	43	RCL	
244	00	00	
245	59	INT	Which program was called
246	22	INV	
247	42	STO	
248	12	12	WR
249	02	2	
250	87	IFF	Continue calculation 2 in Pgm 3
251	05	05	
252	01	01	
253	43	RCL	Return without printing WR if call was not to program 2 (being used as subroutine)
254	11	11	
255	22	INV	
256	43	RCL	
257	12	12	
258	98	RTN	
259	76	LBL	Label B.
260	12	B	Q target
261	22	INV	
262	76	LBL	Label PAU (same as A)
263	66	PAU	
264	76	LBL	Label A.
265	11	A	P target
266	86	STF	
267	09	09	
268	91	R/S	Check and print V, VN, K
269	05	05	
270	98	RTN	
271	00	0	
272	85	+	
273	43	RCL	
274	11	11	H
275	22	INV	
276	02	2	
277	03	3	Check & print H
278	36	PGM	
279	04	04	
280	11	A	
281	87	IFF	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
282	07	07	Return if bad limit check
283	68	NOP	
284	76	LBL	Label π WR calculation for P and Q
285	33	x^2	
286	16	A'	Calc. α targets (STF 9 for P target); R03 should contain $Y^{-1/3}$
287	42	STO	
288	04	04	
289	43	RCL	
290	11	11	H
291	29	CP	
292	67	EQ	
293	04	04	$\hat{W} = \alpha$ for H=0.
294	61	61	
295	43	RCL	
296	21	21	AJVN
297	87	IFF	
298	09	09	
299	03	03	
300	14	14	
301	55	÷	p for Q target (Eq. 17)
302	03	3	
303	03	3	
304	95	=	
305	45	YX	
306	08	8	
307	85	+	
308	01	1	
309	95	=	
310	25	1/X	
311	61	GTO	
312	03	03	
313	38	38	
314	55	÷	p for P target (Eq. 9)
315	93	.	
316	03	3	
317	03	3	
318	03	3	
319	75	-	
320	33	LNX	
321	85	+	
322	09	9	
323	93	.	
324	05	5	
325	85	+	
326	03	3	
327	93	.	
328	03	3	

STEP	CODE	KEY	COMMENTS
329	33	x^2	
330	95	=	
331	94	+/-	
332	22	INV	
333	33	LNX	
334	65	×	
335	93	.	
336	06	6	
337	95	=	
338	42	STO	
339	05	05	p
340	16	A'	Calculate $x_0 = \hat{H}$ opt.
341	42	STO	
342	01	01	
343	43	RCL	H
344	11	11	
345	55	÷	
346	43	RCL	$x_0 Y^{1/3} = H$ opt.
347	95	=	
348	45	YX	
349	48	EXC	p; R05 $\leftarrow \frac{H}{x_0 Y^{1/3}}$ $\frac{H}{H_0}$
350	05	05	
351	95	=	
352	48	EXC	$\left(\frac{H}{x_0 Y^{1/3}}\right)^P$
353	04	04	
354	42	STO	α
355	12	12	
356	16	A'	Calculate $\alpha(a+1)$
357	55	÷	
358	32	X:T	
359	43	RCL	α
360	12	12	
361	75	-	
362	01	1	
363	95	=	a
364	49	PRD	
365	14	14	
366	69	OP	$R_{04} = 1+a\left(\frac{H}{H_0}\right)^P$
367	24	24	
368	43	RCL	H
369	05	05	H_0
370	32	X:T	$\alpha(a+1)$
371	48	EXC	α
372	12	12	
373	49	PRD	$R_{04} = \alpha\left(1+a\left(\frac{H}{H_0}\right)^P\right)$
374	04	04	
375	01	1	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
376	77	GE	Continue if
377	04	04	$1 < \frac{H}{H_0}$
378	61	61	
379	69	□P	
380	35	35	$R_{05} = \frac{H}{H_0} - 1$
381	43	RCL	
382	21	21	AJVN
383	87	IFF	
384	09	09	
385	04	04	
386	14	14	
387	75	-	Calculate b for Q
388	02	2	target (Eq. 19)
389	04	4	
390	95	=	
391	33	X²	
392	85	+	
393	09	9	
394	95	=	
395	35	1/X	
396	65	×	
397	04	4	
398	93	.	
399	06	6	
400	85	+	
401	93	.	
402	00	0	
403	03	3	
404	65	×	
405	43	RCL	
406	21	21	
407	95	=	b
408	65	×	
409	43	RCL	$\frac{H}{H_0} - 1$
410	05	05	
411	61	GTO	
412	04	04	
413	55	55	
414	85	+	
415	02	2	Calculate x' for P
416	06	6	target (Eq. 11)
417	95	=	
418	45	Y^x	
419	04	4	
420	55	÷	
421	04	4	
422	05	5	

STEP	CODE	KEY	COMMENTS
423	53	EE	
424	08	8	
425	95	=	
426	35	1/X	
427	55	÷	
428	43	RCL	H opt
429	01	01	
430	75	-	
431	01	1	
432	95	=	
433	32	INV	
434	49	PRD	$R_{05} = \frac{\frac{H}{H_0} - 1}{\frac{H'}{H_0} - 1}$
435	05	05	
436	43	RCL	
437	05	05	
438	45	Y^x	
439	53	(	
440	93	.	Calculate γ (Eq. 12)
441	01	1	
442	85	+	
443	43	RCL	AJVN
444	21	21	
445	55	÷	
446	03	3	
447	07	7	
448	54	)	
449	32	INV	
450	23	LNX	$\left(\frac{H/H_0 - 1}{H'/H_0 - 1}\right)^{\gamma}$
451	65	×	
452	43	RCL	
453	12	12	$\hat{W}_{max}$
454	33	LNX	
455	95	=	
456	14	+/-	
457	32	INV	
458	23	LNX	
459	49	PRD	(Eq. 5)
460	04	04	
461	43	RCL	$\widehat{WR}$
462	04	04	
463	61	GTO	
464	02	02	
465	30	30	
466	07	7	Calculate ι for P
467	93	.	target (Eq. 6)
468	06	6	
469	03	3	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
470	75	-	
471	06	6	
472	35	1/X	
473	15	E	
474	07	7	
475	00	0	
476	02	2	
477	07	7	
478	75	-	
479	01	1	
480	06	6	
481	35	1/X	
482	15	E	
483	00	0	
484	95	=	α
485	92	RTN	
486	43	RCL	Calculate $\hat{W}$ max for P target
487	21	21	
488	75	-	
489	02	2	
490	06	6	
491	95	=	
492	33	X^2	
493	77	GE	
494	25	CLR	
495	15	15	
496	65	×	
497	53	(	
498	04	04	
499	65	×	
500	33	X^2	
501	85	+	
502	53	(	
503	44	+/-	
504	65	×	
505	03	3	
506	01	1	
507	85	+	
508	01	1	
509	03	3	
510	04	4	
511	00	0	
512	01	GTO	
513	00	00	
514	11	11	
515	55	÷	
516	01	1	

STEP	CODE	KEY	COMMENTS
517	06	6	
518	00	0	
519	95	=	a (Eqs. 7, 8)
520	85	+	
521	01	1	
522	95	=	
523	65	×	
524	43	RCL	
525	12	12	α
526	95	=	
527	92	RTN	$\hat{W}_{max}$
528	65	×	Calculate x_0 for Q (Eq. 18)
529	93	.	
530	02	2	
531	04	4	
532	33	X^2	
533	95	=	
534	22	INV	
535	23	LNX	
536	34	FX	
537	65	×	
538	53	(	
539	03	9	
540	06	6	
541	00	0	
542	75	-	
543	04	4	
544	01	1	
545	00	0	
546	65	×	
547	53	(	
548	53	(	
549	93	.	
550	02	2	
551	07	7	
552	55	÷	
553	43	RCL	AJVN
554	21	21	
555	45	Y^x	
556	01	1	
557	93	.	
558	02	2	
559	75	-	
560	06	6	
561	93	.	
562	05	5	
563	54	)	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
564	32	INV	
565	33	LNX	
566	55	÷	
567	53	(	
568	04	CE	
569	35	+	
570	01	1	
571	95	=	
572	92	RTN	x_0
573	93	.	Check & print
574	01	1	Y, VN, K;
575	36	PGM	Calculate AJVN, max HOB
576	09	09	
577	17	B'	
578	00	0	
579	61	GTO	
580	94	+/-	
581	98	ADV	Go to Page 3 to
582	36	PGM	print WR, calc. P_d
583	03	03	
584	12	B	
585	92	RTN	
586	65	×	VN adjustment factor,R,
587	53	(	for P target (Eq. 2)
588	33	X^2	
589	75	-	
590	43	RCL	$\frac{K}{10} - 1$
591	04	04	
592	54	)	
593	34	$\sqrt{x}$	
594	95	=	
595	42	STO	R
596	21	21	
597	15	CLR	Continuation of SBR +/-
598	43	RCL	
599	21	21	
600	33	LNX	ℓnR
601	55	÷	
602	08	8	
603	93	.	C for Q target
604	02	2	
605	32	X:T	
606	11	1	C for P target
607	01	1	
608	18	C'	
609	85	+	
610	42	STO	

STEP	CODE	KEY	COMMENTS
611	05	05	AJVN-VN = C(ℓnR) → R05
612	43	RCL	
613	13	13	VN
614	95	=	
615	42	STO	AJVN
616	21	21	
617	01	1	
618	03	3	Initialize for printing
619	42	STO	routines in Pgm 9
620	02	02	
621	43	RCL	
622	05	05	k(ℓnR)
623	75	-	
624	50	IXI	
625	95	=	
626	94	+/-	Lower limit on VN =
627	55	÷	
628	02	2	max {0,-C(ℓnR)}
629	85	+	
630	53	(	
631	03	3	Upper limit for Q target
632	04	4	= 34 - C(ℓnR)
633	32	X:T	
634	05	5	Upper limit for P target
635	06	6	= 56 - C(ℓnR)
636	18	C'	
637	75	-	
638	43	RCL	Given alphanumeric
639	01	01	(step 115)
640	32	X:T	
641	43	RCL	
642	05	05	C(ℓnR)
643	54	)	
644	36	PGM	Check and print VN
645	09	09	
646	13	C	
647	43	RCL	
648	01	01	Given alphanumeric
649	75	-	
650	01	1	
651	06	6	
652	95	=	Alpha for K
653	32	X:T	
654	00	0	
655	85	+	
656	09	9	
657	36	PGM	Check & print K

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS	STEP	CODE	KEY	COMMENTS
658	09	09					
659	13	C	----------				
660	01	1					
661	04	4	Calculate H max, the				
662	32	X:T	upper limit on HOB				
663	43	RCL	AJVN				
664	21	21					
665	87	IFF					
666	09	09					
667	06	06					
668	78	78	----------				
669	77	GE	Q target calc.				
670	06	06					
671	78	78					
672	09	9					
673	00	0					
674	00	0					
675	61	GTO					
676	06	06					
677	90	90	----------				
678	55	÷	P target calc.				
679	01	1					
680	05	5					
681	94	+/-					
682	95	=					
683	22	INV					
684	23	LNX					
685	65	×					
686	02	2					
687	03	3					
688	00	0					
689	08	8					
690	55	÷					
691	43	RCL	$Y^{-1/3}$				
692	03	03					
693	95	=					
694	32	HIR	H max) set up to				
695	02	02	) use in				
696	00	0	) printing				
697	32	HIR	H min = 0) routines				
698	01	01					
699	32	RTN					

Section 3: Programs 3.0 - 3.2

Probability of Damage to Point and Circular Targets
With Normal or Uniform Target Element Distributions.

DNA	AP-550 PROMPT AI			HTI
Pd to POINT and CIRCULAR TARGETS, NORMAL and UNIFORM DIST.				
CEP (ft)	Target Radius (ft)	Offset (ft)	Damage Sigma	3.n · Pd
		Weapon Radius (ft)		

SOURCES OF DATA:

Defense Intelligence Agency, Physical Vulnerability Handbook-Nuclear Weapons (U), AP-550-1-2-60-INT, June 1, 1969, Part IV, Section A.

DESCRIPTION:

A. Objective

The objective of this set of 3 programs is to calculate the probability of damage (Pd) to point and circular area targets. Normal and uniform target element distributions are considered. For area targets, the probability of damage is equivalent to the expected proportion of the target to be damaged. The adjusted CEP methodology is utilized to compute the Pd to circular targets. Auxiliary magnetic card programs for computing Pd to area targets of geometries other than circular by the weighted average point method are given in Appendix D.

B. Inputs-Outputs

The three calculations comprising this program set and their necessary inputs are as follows:

Program 3.0: Pd to point targets,

Inputs: Weapon radius (ft)
CEP (ft)
Offset (ft)
Damage sigma

Program 3.1: Pd to circular normal targets,

Inputs: same as 3.0 with the addition of target radius (ft)

Program 3.2: Pd to circular uniform targets.

Inputs: same as 3.1

C. Limits

Weapon radius (WR):	$WR \geq 0$ ft
CEP:	$CEP \geq 0$ ft
Target radius (TR):	$TR \geq 0$ ft
Offset (x):	$x \geq 0$ ft
Damage sigma (σ):	$0.1 \leq \sigma \leq 0.5$

D. Data Storage Locations, Printer Alphanumerics

The user can find the following information stored in the indicated registers (R):

Variables	Registers	Alphanumerics
Weapon radius (ft)	R12	W
CEP (ft)	R15	C
Target radius (ft)	R16	T
Offset (ft)	R17	X
Damage sigma	R18	S
Prob. of Damage	only in display	P

E. Additional Information

Pressing R/S will initiate the previously keyed-in type of calculation even if the inputs are changed. Several CROM programs require an input of target radius (TR). If one of these programs is run prior to the point target calculation and the calculator is not turned off, then on, the value of the target radius previously entered will be printed when the point target calculation is initiated. At all times, however, a target radius of zero will be used internally for the point target calculation.

EXAMPLE 3.0, 3.1, 3.2

Given the following information, calculate the probability of damage to a point target, circular target of normal distribution and radius of 500 ft and a circular target of uniform distribution and radius of 1000 ft.

Weapon radius = 8500 ft
Damage sigma = 0.2
Offset distance = 6000 ft
CEP = 1000 ft

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
1	Turn off, then on			0	
2	Select program 01		2nd Pgm 01	0.	
3	Enter weapon radius (ft)	8500	C	8500.	
4	Enter CEP (ft)	1000	2nd A'	1000.	
5	Enter offset (ft)	6000	2nd C'	6000.	
6	Enter damage sigma	.2	2nd D'	0.2	
7	Calc. Pd - point target	3.0	2nd E'		3. 8500. W 1000. C 0. T 6000. X 0.2 S
				0.9	0.9 P
8	Enter Target 2 radius (ft)	500	2nd B'	500.	
9	Calc. Pd - circular target normal distribution	3.1	2nd E'		3.1 8500. W 1000. C 500. T 6000. X 0.2 S
				0.899	0.899 P

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
10	Enter Target 3 radius (ft)	1000	2nd B'	1000.	
11	Calc. Pd - circular target uniform distribution	3.2	2nd E'		3.2 8500. W 1000. C 1000. T 6000. X 0.2 S
				0.889	0.889 P

EQUATIONS

Definitions

P = probability of damage
WR = weapon radius
CEP = circular error probable
TR = target radius
X = offset
σ = damage sigma
CEP_a = adjusted CEP
$\hat{W} = WR/CEP_a$
$\hat{x} = X/CEP_a$
ε = offset at which P = .5
ε' = offset at which P = .98

Calculation of adjusted CEP:

$$CEP_a = \sqrt{CEP^2 + K \times TR^2} \tag{1}$$

where

K = 0, for point targets
K = .231, for normally distributed area targets

For uniform target distributions,

K = .4, if WR + CEP + X $\geq$ TR
= .5 otherwise.

Calculation of probability:

$$P = (1 + \exp(R))^{-1}, \text{ where } R = R(\hat{x}, \hat{W}, \sigma): \tag{2}$$

For $\hat{W} > 30$, $R = -.07Z^3 - 1.6Z$, where $Z = \dfrac{\ln[(1-\sigma^2)WR/X]}{\sqrt{-\ln(1-\sigma^2)}}$ (3)

For $\hat{W} \leq 30$,

$$R = R', \text{ if } \hat{x} \geq 2 \tag{4}$$

$$= R' + \cos(45\hat{x})\left(R_0 + \frac{\hat{x}}{.9} - R'\right), \text{ if } \hat{x} < 2 \tag{5}$$

where

$$R' = a(\hat{W},\sigma)\frac{L(\hat{x},\hat{W},\sigma)}{L'} + [1-a(\hat{W},\sigma)]\frac{T(\hat{x},\hat{W},\sigma)}{T'} \quad (6)$$

$$R_0 = (3.6\sigma-2)\hat{W} - (1.3+1.1\sigma)\ell n[\hat{W}(.24+\sigma)] \quad (7)$$

$$a(W,\sigma) = \exp\left[-\left(\frac{1339\exp(-42\sigma) - 2\sigma + 3.7}{W}\right)^{(.71\exp(\frac{\sigma}{.3}))}\right] - (\gamma + |\gamma'|) \quad (8)$$

$$\gamma = 7000\sigma^{5.6}\exp(-21\sigma)(\hat{W} - 5.5) \quad (9)$$

$$T(x,W,\sigma) = q\tan(90) \quad , \text{ if } b(\hat{x}-\varepsilon) > 90 \quad (10)$$

$$= q\tan(-90) \quad , \text{ if } b(\hat{x}-\varepsilon) < -90$$

$$= q\tan(b(\hat{x}-\varepsilon)), \text{ otherwise}$$

$$T' = \tan(b(\varepsilon'-\varepsilon)) \quad (11)$$

$$L = q\ell n\left[\max\left\{\frac{\hat{x}-\varepsilon'+2}{\varepsilon-\varepsilon'+2}, 0\right\} + 10^{-5}\right] \quad (12)$$

$$L' = \ell n\left[\max\left\{\frac{2}{\varepsilon-\varepsilon'+2}, 0\right\} + 10^{-5}\right] \quad (13)$$

$$q = \ell n\left(\frac{1}{.98} - 1\right) \simeq -3.89 \quad (14)$$

$$\varepsilon = \hat{W} - .2 - (\gamma + |\gamma'|) \quad (15)$$

$$\gamma = .61(\hat{W} + 4\sigma - 3.2)(\sigma^{2.23} + 10^{-5}\sigma^{-2.23}) \quad (16)$$

$$\varepsilon' = \ell n\left\{.6\sigma + \left[\frac{1}{1.2}\exp(10\sigma - 1.1\hat{W}) + \frac{1}{299}\exp\left(-\frac{W}{.9}\exp(2.69\sigma) - 2.7\sigma + 9.47\sigma\right)\right]^{-1}\right\} \quad (17)$$

$$b = 26\exp(-2.1\sigma - W/16) \quad (18)$$

All trigonometric arguments are in degrees.

PARTITION	FLAG	COMMENTS	FLAG	COMMENTS
AUTOMATIC	02	Suppresses printing of probability		
LIBRARY MODULE: CROM A-1 (Program 3)	07	Test for limit check error		

DATA REGISTERS FOR EXAMPLE 3.0

DATA	REG.	COMMENTS
3.	00	Code for called program
0. 5	01	WR, W, $\sigma^2 - 1$
19.	02	indirect recall (Pgm 9)
1000.	03	CEP_a
5000.	04	D_i, x
0.	05	alphanumeric for D_i
0.	06	(calc. 3.3)
0.	07	
0.	08	not used
0.	09	
0.	10	
0.	11	HOB (from Pgm 2)
3500.	12	WR
.	13	
0.	14	not used
1000.	15	CEP
.	16	Target radius
2000.	17	Offset
0. 3	18	Damage sigma
0.	19	not used
[illegible]	20	x, R'
[illegible]	21	-c
[illegible]	22	c'
[illegible]	23	b
[illegible]	24	a
[illegible]	25	R_0
[illegible]	26	T
[illegible]	27	L'
[illegible]	28	
[illegible]	29	P_i (for calc. 3.3)

LABELS STEP	CODE	KEY	COMMENTS
001	16	A'	e^{-x}
013	17	B'	tangent func.
040	18	C'	log function
064	19	E'	R-P
078	1A	D'	used by LBL D
097	1B	A	calc. P
179	13	-	calc. 3.2
205	12	E	calc. 3.1
214	11	A	calc. 3.0
307	14	D	calc. 3.3
348	15	E	calc. coeffs.

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS	STEP	CODE	KEY	COMMENTS
000	76	LBL	Label A'.	047	43	RCL	→
001	[illegible]	A'		048	31	31	
002	[illegible]	[illegible]		049	75	-	
003	[illegible]	[illegible]	.	050	43	RCL	
004	[illegible]	[illegible]		051	32	32	ε'
005	[illegible]	[illegible]	$e^{-(\cdot x)}$∧ ...	052	95	=	
006	[illegible]	[illegible]		053	55	÷	
007	[illegible]	INV		054	02	2	
008	[illegible]	LNX		055	85	+	
009	[illegible]	[illegible]		056	50	I×I	
010	[illegible]	RTN		057	85	+	
011	[illegible]	LBL	Label B'.	058	01	1	
012	[illegible]	B'	x = display (x or ε')	059	52	EE	(if ·0 set to 10^{-5})
013	[illegible]	-		060	05	5	
014	[illegible]	[illegible]		061	94	+/-	(guard digit)
015	[illegible]	RCL	-	062	95	=	
016	[illegible]	[illegible]		063	23	LNX	
017	[illegible]	=		064	92	RTN	
018	[illegible]	[illegible]		065	76	LBL	Label E'.
019	[illegible]	RCL	b	066	10	E'	
020	[illegible]	[illegible]		067	00	0	
021	[illegible]	=		068	95	=	
022	[illegible]	[illegible]		069	94	+/-	
023	[illegible]	[illegible]		070	22	INV	
024	[illegible]	[illegible]		071	23	LNX	
025	[illegible]	EE		072	85	+	$\frac{1}{e^{-x}+1}$
026	[illegible]	[illegible]		073	01	1	
027	[illegible]	[illegible]	If b(x-·) > 90, set=90	074	95	=	
028	[illegible]	[illegible]		075	35	1/X	
029	[illegible]	+/-	If b(x-ε) ≤ -90, set=-90	076	92	RTN	
030	[illegible]	INV		077	76	LBL	Label D'.
031	[illegible]	EE		078	19	D'	
032	[illegible]	00		079	44	SUM	ΣP_i
033	[illegible]	[illegible]		080	38	38	(for option 2.3)
034	[illegible]	[illegible]		081	69	OP	
035	[illegible]	[illegible]		082	15	15	
036	[illegible]	DEG		083	43	RCL	
037	[illegible]	TAN	tan[b(x-ε)]	084	15	05	Alphanumerics for D_i
038	92	RTN		085	36	PGM	
039	76	LBL	Label C'.	086	19	19	
040	[illegible]	C'		087	18	C'	
041	[illegible]	2		088	42	STO	
042	95	=	... + 2	089	04	04	D_i
043	55	÷	(2+· - ')	090	87	IFF	(if WR CEP 30)
044	[illegible]	[illegible]		091	07	07	
045	02	2		092	05	05	
046	75	-		093	85	85	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
094	73	RCL	
095	33	X↑T	$D_i/CEP_a = \hat{D}_i$
096	21	LBL	Label ADV
097	83	ADV	
098	42	STO	Offset=x (x or $\hat{D}_i$)
099	00	00	
100	71	B'	Tangent part of R
101	33	X↑T	
102	43	RCL	
103	00	00	
104	75	-	
105	43	RCL	
106	22	22	ε'
107	85	+	
108	18	C'	Logarithmic part of R
109	33	X↑T	
110	85	+	
111	43	RCL	T'
112	34	34	
113	75	-	
114	14	CE	
115	33	X↑T	
116	43	RCL	L'
117	35	35	
118	75	-	
119	43	RCL	a
120	24	24	
121	65	×	
122	01	1	
123	00	0	
124	75	-	-q
125	43	RCL	-R' = $-q\frac{T}{T'}-\frac{L}{L'}$
126	24	24	
127	55	÷	
128	43	RCL	-R'/x
129	24	24	
130	65	×	
131	43	RCL	If x < 2:
132	00	00	(
133	02	2	
134	01	1	
135	00	0	
136	55	÷	x/.9
137	43	RCL	
138	00	00	
139	85	+	+
140	43	RCL	
141	00	00	R_0
142	75	-	-
143	43	RCL	
144	00	00	R'
145	54	)	)
146	01	1	
147	05	5	...cos(45x) ...
148	65	×	
149	43	RCL	
150	44	44	
151	85	+	
152	01	1	
153	00	0	
154	00	0	
155	55	÷	
156	43	RCL	
157	00	00	
158	54	)	
159	61	E'	Calculate P from R
160	44	IFF	
161	02	02	
162	00	00	(return without print-
163	10	10	ing if flag 2 set)
164	33	X↑T	
165	03	3	
166	03	3	"P"
167	33	X↑T	
168	31	INV	
169	44	STF	
170	01	01	
171	00	00	
172	36	PAU	
173	44	PSE	
174	00	00	
175	14	E	Print Probability
176	44	FIX	
177	02	02	
178	21	LBL	Label C.
179	13	C	Pd for Circular Uniform
180	44	FIX	Targets
181	00	00	
182	01	1	
183	44	PSE	
184	00	00	
185	85	+	
186	44	FIX	
187	00	00	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
188	85	+	
189	43	RCL	If WR + CEP + x ≥ TR,
190	17	17	then K = .4
191	95	=	
192	47	CE	
193	01	01	
194	98	98	
195	93	.	
196	01	1	
197	85	+	
198	93	.	
199	04	4	
200	95	=	
201	61	GTO	
202	02	02	(K in display)
203	16	16	
204	16	LBL	Label B.
205	12	B	Pd for Circular Normal
206	93	.	Targets
207	02	2	
208	03	3	K for normally
209	01	1	distributed area
210	61	GTO	targets
211	13	13	
212	16	16	
213	16	LBL	Label A.
214	11	A	Pd for Point Targets
215	00	0	K for point targets
216	16	16	Labels A,B,C start here
217	14	14	Label D starts here
218	03	03	
219	43	RCL	TR
220	13	13	
221	85	+	
222	43	RCL	CEP
223	11	11	
224	95	=	
225	34	$\sqrt{x}$	$CEP_a = \sqrt{CEP^2 + K \cdot TR^2}$
226	42	STO	
227	00	00	
228	04	4	"W"
229	16	16	
230	14	14	
231	43	RCL	

STEP	CODE	KEY	COMMENTS
235	13	13	
236	50	I×I	WR ≥ 0
237	36	PGM	
238	09	09	WR (round to 3 signif-
239	13	B	icant digits)
240	42	STO	
241	12	12	
242	42	STO	
243	01	01	(set up for $\bar{x}$)
244	93	.	
245	04	4	
246	32	X≠T	
247	43	RCL	Return after
248	00	00	printing WR if
249	33	INV	Frac(R00) ≥ .4
250	39	INT	
251	14	14	
252	16	16	
253	16	16	
254	16	16	
255	16	16	Set up automatic
256	16	16	increment for
257	16	16	printing parameters.
258	16	16	
259	16	16	
260	16	16	
261	16	16	
262	16	16	
263	16	16	
264	16	16	
265	16	16	
266	16	16	
267	16	16	
268	16	16	
269	16	16	
270	16	16	
271	16	16	
272	16	16	
273	16	16	
274	16	16	
275	16	16	
276	16	16	
277	16	16	
278	16	16	
279	16	16	
280	85	+	
281	93	.	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
282	05	5	$.1 \leq \sigma \leq .5$
283	36	PGM	
284	09	09	
285	18	C	Print sigma
286	33	X^2	σ^2
287	75	-	
288	53	(	
289	34	X	WR/CEP_a
290	75	-	
291	03	3	
292	00	0	
293	54	)	
294	32	X↑T	
295	00	0	
296	22	INV	
297	73	GE	} (if $\frac{WR}{CEP_a} \geq 30$)
298	05	05	}
299	80	80	
300	35	CLR	Otherwise, CLEAR and start fit
301	15	E	
302	79	X	
303	32	X↑T	X/CEP_a
304	61	GTO	
305	98	ADV	
306	76	LBL	Label D.
307	14	D	
308	35	CLR	Calculates probability of damage to rectangular targets
309	42	STO	
310	38	38	
311	71	SBR	
312	03	03	
313	11	1	
314	55	÷	
315	01	1	
316	00	0	
317	42	STO	
318	02	02	
319	01	1	
320	00	0	
321	00	0	
322	01	1	
323	42	STO	
324	05	05	
325	00	0	
326	85	+	
327	14	D*	
328	14	D*	

STEP	CODE	KEY	COMMENTS
329	69	DP	
330	22	22	
331	14	D*	
332	14	D*	
333	85	+	
334	43	RCL	
335	28	28	
336	95	=	
337	55	÷	
338	01	1	
339	00	0	
340	95	=	
341	22	INV	
342	86	STF	
343	02	02	
344	61	GTO	
345	01	01	
346	00	0	
347	76	LBL	Label E.
348	15	E	Calculate σ, σ', a, b, R_0
349	79	X	
350	42	STO	$\hat{W}$ = WR/CEP_a
351	01	01	
352	55	÷	Calculate b (Eq. 18)
353	01	1	
354	06	6	
355	05	5	
356	03	3	
357	11	1	
358	07	7	
359	14	D*	
360	13	B	
361	02	2	
362	01	1	
363	00	0	
364	95	=	
365	42	STO	b
366	04	04	
367	14	D*	Calculate a (Eq. 8)
368	12	A	
369	01	1	
370	00	0	
371	00	0	
372	01	1	
373	42	STO	
374	03	03	
375	43	RCL	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
			$\frac{1339\,e^{-42c} - 2c + 3.7}{W}$
			$.71 \exp\left(\frac{1}{.3}\right)$
			Calculate , (Eq. 9)
			W

STEP	CODE	KEY	COMMENTS
			a
			Calculate k_0 (Eq. 17)

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
470	18	18	
471	95	=	
472	42	STO	R_0
473	00	00	
474	43	RCL	
475	18	18	Calculate -ε (Eq. 15)
476	45	Y^x	
477	03	3	
478	95	=	
479	00	0	
480	00	0	
481	85	+	
482	01	1	
483	95	=	
484	01	1	
485	02	EE	
486	05	05	
487	95	=	
488	04	4	
489	00	0	
490	06	6	
491	07	7	
492	85	+	
493	43	RCL	
494	01	01	
495	85	+	
496	04	4	
497	95	=	
498	43	RCL	
499	18	18	
500	55	÷	
501	03	3	
502	00	0	
503	65	×	
504	95	=	
505	85	+	
506	01	1	
507	85	+	
508	43	RCL	
509	01	01	
510	95	=	
511	42	STO	
512	21	21	(-)

STEP	CODE	KEY	COMMENTS
517	02	2	Calculate σ' (Eq. 17)
518	00	0	
519	00	0	
520	00	0	
521	16	A'	
522	43	RCL	
523	01	01	W
524	55	÷	
525	09	9	
526	00	0	
527	85	+	
528	02	2	
529	03	3	
530	04	4	
531	05	5	
532	43	RCL	
533	18	18	
534	65	×	2.7·n·
535	05	5	
536	00	0	
537	03	3	
538	04	4	
539	07	7	
540	16	A'	
541	00	0	
542	00	0	
543	00	0	
544	35	1/x	$299\exp\left[\frac{-W}{.9}e^{-2.69\cdot} - 2.7\cdot n\cdot + 9.47\cdot\right]$
545	85	+	
546	05	5	
547	01	1	
548	03	3	
549	01	1	
550	05	5	
551	43	RCL	
552	01	01	
553	55	÷	
554	01	1	
555	00	0	
556	16	A'	exp[10·-1.1WR]
557	01	1	
558	03	3	
559	02	2	
560	05	5	
561	95	=	
562	05	5	
563	85	+	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
			$\tan[b(\quad)]$ Coefficient for tangent function, T' $\ln\left[\max\left\{0,\frac{2}{2+\quad}\right\}+10^{-5}\right]$ Coefficient for logarithm function, L'
			Case for $\frac{WR}{CEP_a} > 30$ $?-1$ WR x $?-1$ $\ln\frac{(1-\quad)WR}{x}\quad z$ $\sqrt{-\ln(1-\quad)}$ (Note: $\ln x = \ln(-x)$ and $\sqrt{x} = \sqrt{-x}$ to the calculator.)

STEP	CODE	KEY	COMMENTS
			$P = [\exp(-.07z^3-1.6z)+1]^{-1}$ (Eq. 3) Flag 7 set for $\hat{W} > 30$
			When Frac(ROO) $\geq$ .4, put HOB into t register, and WR in display and return (to Pgm 2).

Section 4: Programs 4.0 and 4.1

Personnel Vulnerability, Weapon Radius Determination.

DNA	AP-550 PROMPT AI				HTI
PERSONNEL VULNERABILITY					
				4.n → WR	
Yield (KT)	HOB (ft)	Environment Select			

SOURCE OF DATA:

Defense Intelligence Agency, Physical Vulnerability Handbook-Nuclear Weapons (U), AP-550-1-2-60-INT, June 1, 1969, Part III, Section A.

DESCRIPTION:

A. Objective

The objective of this set of two programs is to evaluate weapon radii for fatalities or incapacitating casualties to unwarned personnel in various environments. Program 4.0 calculates weapon radii and presents damage sigmas for any HOB and program 4.1 calculates weapon radii and damage sigmas generated by detonation at the near-optimum HOB. Airblast and nuclear radiation effects weapon radii are combined in the manner described on page III-2 of AP-550 to form a combined weapon radius. Thermal radiation effects are considered only for exposed personnel taking no evasive action.

B. Inputs-Outputs

The two calculations comprising this program set and their necessary inputs are as follows:

Program 4.0: Weapon radius and damage sigma - any HOB

Inputs: Yield (KT)
HOB (ft)
Environment (see subsection E below)

Program 4.1: Weapon radius and damage sigma - near-optimum HOB

Inputs: Yield (KT)
Environment (see subsection E below)

C. Limits

Yield: $0.1 \text{ KT} \leq Y \leq 30 \text{ MT}$

HOB: $0 \text{ ft/KT}^{1/3} \leq \text{SHOB} \leq 1000 \text{ ft/KT}^{1/3}$

where

SHOB = scaled HOB

Environment: Env. = 1,2,3,...20

D. Data Storage Locations, Printer Alphanumerics

The user can find the following information stored in the indicated registers (R):

Variables	Registers	Alphanumerics
Yield	R10	Y
HOB (pgm. 4.0)	R11	H
Environment	not retained	E
Weapon radius	only in display	W
Optimum HOB (pgm. 4.1)	R11	H
Damage Sigma	R18	S

E. Personnel Environments

The following personnel and environment indices are to be used in conjunction with the personnel vulnerability programs. The index number associated with each environment description is to be entered with key C when executing these programs.

Environment		Index
Personnel in wood frame, wall bearing and adobe buildings, and forests		
	Fatalities	1
	Incapacitating casualties	2
Personnel in multistory residential, commercial or industrial buildings. Steel or reinforced concrete framed		
	Fatalities	3
	Incapacitating casualties	4
Personnel in basements		
	Fatalities	5
	Incapacitating casualties	6

Personnel in foxholes		
	Fatalities	7
	Incapacitating casualties	8
Personnel in tanks		
	Fatalities	9
	Incapacitating casualties	10
Personnel in deliberate underground shelters (2 ft. earth cover).		
	Fatalities	11
	Incapacitating casualties	13
Personnel in expedient underground shelters (2 ft. earth cover).		
	Fatalities	12
	Incapacitating casualties	14
Personnel in underground command posts		
	Fatalities and Incapacitating casualties	15
Personnel in open rural and open urban areas		
	Fatalities	16
	Incapacitating casualties	17
Personnel in urban areas		
	Any injury	18
Exposed personnel taking no evasive action		
	Thermal fatalities	19
	Thermal incapacitating casualties	20

F. Special Features

The environment index number is not stored during program execution; therefore, it must be re-entered each time programs 4.0 or 4.1 are run.

EXAMPLE 4.0, 4.1

Given the following information, calculate the weapon radii and damage sigmas for a contact burst and a near-optimum height of burst.

Yield = 100 KT

Environment: Index number = 1.

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
1	Turn off - then on			0	
2	Select program 01		2nd Pgm 01	0.	
3	Enter yield (KT)	100	A	100.	
4	Enter HOB (ft)	0	B	0.	
5	Enter environment index	1	C	1.	
6	Calculate weapon radius and damage sigma	4.0	2nd E'		4. 100. Y 1. E 0. H 0.318 S 7070. 7070. W
7	Calculate weapon radius and damage sigma for near-optimum HOB				
8	Re-enter environment index	1	C		
9	Initiate calculation	4.1	2nd E'		4.1 100. Y 1. E 3713.* H 0.392 S 9830. 9830. W
	Note: The near-optimum HOB is printed with the inputs in an unrounded format.				
	*prints as 3713.271067				

EQUATIONS

Definitions

Y = yield (KT)

HOB = height of burst, feet

$\hat{H}$ = scaled HOB = $HOB/Y^{1/3}$

E = environment category

WR = weapon radius

σ = damage sigma (calculated by the CROM)

Q(x) = approximation to the complement of the cumulative normal distribution

V, M, K, x_0, σ_B, σ_R, are parameters for the first 18 environment categories that are stored in look-up tables in the CROM.

E	V	$100y_1$	10K	$.01x_0$	$10\sigma_B$	$10\sigma_R$
1	12	20	62	8	4	2
2	5	28	43	10	5	2
3	14	26	62	7	3	3
4	5	33	43	10	4	3
5	16	28	62	7	4	5
6	7	36	33	9	4	5
7	21	14	0	0	2	3
8	16	23	0	5	3	3
9	21	21	0	0	3	3
10	17	29	0	0	3	3
11	27	0	20	0	5	5
12	21	0	0	0	4	5
13	16	12	0	5	4	5
14	10	12	0	8	4	5
15	31	0	30	0	3	3
16	10	25	54	9	5	2
17	7	33	62	9	5	2
18	4	41	50	9	5	3

Table 4.1. Parameters for the first 18 environment categories.

For the first 18 categories, WR is calculated by combining a blast weapon radius with a radiation weapon radius:

$$WR = \left[WR_B^2 \, Q\left(\frac{1}{\beta} \ln\left(\frac{WR_R}{WR_B}\right) - \beta\right) + WR_R^2 \, Q\left(\frac{1}{\beta} \ln\left(\frac{WR_B}{WR_R}\right) - \beta\right)\right]^{\frac{1}{2}} \tag{1}$$

$$\langle r \rangle = \langle r_B \rangle Q\left(\frac{1}{\beta} \ln\left(\frac{WR_R}{WR_B}\right) - \frac{\beta_R^2}{\beta}\right) + \langle r_R \rangle Q\left(\frac{1}{\beta} \ln\left(\frac{WR_B}{WR_R}\right) - \frac{\beta_B^2}{\beta}\right) \tag{2}$$

$$\beta = \left[1 - \frac{\langle r \rangle^2}{WR^2}\right]^{\frac{1}{2}} \tag{3}$$

where:

$$Q(x) = 1 - \left[1 + \exp(-x(1.6 + .07x^2))\right]^{-1}, \tag{4}$$

$$\beta_R^2 = -\ln(1 - \sigma_R^2), \quad \beta_B^2 = -\ln(1 - \sigma_B^2), \quad \beta^2 = \beta_B^2 + \beta_R^2, \tag{5}$$

$$\langle r_R \rangle = WR_R \exp\left(\frac{-1}{2}\beta_R^2\right), \tag{6}$$

$$\langle r_B \rangle = r_{50}(\text{blast}) \exp\left(\frac{1}{2}\beta_B^2\right), \tag{7}$$

$$WR_B = \langle r_B \rangle \exp\left(\frac{1}{2}\beta_B^2\right) \text{ and} \tag{8}$$

r_{50}(blast) is obtained from calculating WR from the P-target code (which assumes $\sigma_B = .2$), and converting it to r_{50}(blast) by

$$r_{50}(\text{blast}) = (1-\sigma_B^2)WR(\text{blast}) = .96WR(\text{blast}). \tag{9}$$

The radiation component of the weapon radius is calculated as follows:

$$WR_R = WR_0 \exp\left\{-.01\exp\left(-\frac{.01}{Y^2} - \frac{1}{H}\right)\left[W_H + W_{\cdot} + W_Y\right]\right\} \tag{10}$$

The four parameters, WR_0, W_H, $W_{\cdot}$, W_Y, are calculated as functions of yield and HOB:

$$y_0 = -180 + 10^{(3+y_1)} \tag{11}$$

$$Y_0' = Y_0\left\{1 + \exp\left[-\sqrt{\frac{124}{\hat{H}}} - .6 - \frac{Y_0}{50^2} - .8\left(\frac{\hat{H}}{Y_0}\right)^2\right]\right\} \quad (12)$$

$$m = \log\left(\frac{670}{Y_0'} + \sqrt{1.6}\right) \quad (13)$$

$$W_0 = \frac{a\exp[1.3(y-y_c)]}{1+\exp[1.3(y-y_c)]}\exp(-2/Y^4) \quad (14)$$

where:

$$y = \log Y, \quad (15)$$

$$a = \frac{-1}{4}\left(p - .6 + |p-.6|\right) + .11 + \frac{277\cdot10^3}{Y_0'}, \text{ and} \quad (16)$$

$$y_c = 1 + a/.38. \quad (17)$$

$$WR_0 = Y_0'\ 10^{(m-.5W_0)}Y^m \quad (18)$$

$$W_H = \frac{255 - .18\hat{H} + 161q}{(p+|p|)^{(2.8+q)}}, \text{ for } \hat{H} \leq 700 \quad (19)$$

$$W_H = \frac{255 - .18\hat{H}}{(p+|p|)^{(2.8+q)}}, \text{ for } \hat{H} > 700 \quad (20)$$

where:

$$q = \frac{4}{3}\cos(.9\hat{H})\exp\left(\frac{-.9\hat{H}}{331}\right)\text{and} \quad (21)$$

$$p = 8.5 - 2\ln H - \frac{1}{2}\log Y. \quad (22)$$

(Trigonometric argument is in degrees.)

$$W_Y = \left[1 + \left(\frac{\hat{H}}{620}\right)^2\right]\log Y - 7, \text{ if } P_R = .5 \quad (23)$$

$$= 0, \text{ otherwise}$$

$$W_Y = \ln\left[1 + \exp\left\{13\ \log Y - 30 + \left(\frac{\hat{H}}{169}\right)^2\right\}\right]\left(.8 + 10^{-24}Y_0^{8}\right)^{-1} \quad (24)$$

For environment categories 19 and 20,

$$WR = [a + c(Y-b)^p]^{-1} \text{ where } a, c, b, p \text{ are:} \quad (25)$$

Coefficient	Class 19	Class 20	
$\frac{8 \times 10^{-6}}{a}$	$.8 + .3\exp\left(\frac{\hat{H}}{334}\right)$	$.4 + .7\exp\left(\frac{\hat{H}}{530}\right)$	(26)
$10^{3}\alpha$	$\frac{.1\hat{H}}{667} + .46 + .27\exp\left(\frac{-\hat{H}}{130}\right)$	$\frac{.1\hat{H}}{1100.667} + .37 + .20\exp\left(\frac{-\hat{H}}{140}\right)$	(27)
4b	$.006\exp\left(\frac{\hat{H}}{306}\right)$	$.005\exp\left(\frac{\hat{H}}{340}\right)$	(28)
p	$-.445$	$\left(\frac{19}{18.3}\right)(-.445)$	(29)

PARTITION	FLAG	COMMENTS	FLAG	COMMENTS
AUTOMATIC	02	Supress printing temporarily (copies flag 1)		
LIBRARY MODULE: CROM A-1 (Program 4)	09	Distinguish calc. 4.1 from 4.0		

DATA REGISTERS FOR EXAMPLE 4.0

DATA	REG.	COMMENTS
4.	00	
140531 21321	01	
11.	02	# digits in coefficients
0.2154433433	03	Y-1.3
1251.8110433	04	
-2.127211553	05	used by Pgm 2
0.	06	
0.	07	
0.	08	
0.	09	
100	10	Yield
0.	11	HOB
0.	12	Environment
13.	13	packed coefficients
6.3	14	K
0.	15	
0.	16	
0.	17	
.11145443344	18	
0.	19	V_0
0	20	
2.8712780441	21	AJVN
0.	22	
0.	23	
0.	24	H, scratch
0.	25	.9H, scratch
.1	26	WR, scratch
.0787211054	27	, scratch
22.1.2821.1	28	$-R^2$, scratch
0.5142142943	29	$-B^2$, scratch
5225.9311191	30	R, scratch

STEP	CODE	LABELS KEY	COMMENTS
001	16	A'	data unpacking
015	11	B'	e^{-x}
022	13	C'	x·ogY+1
031	12	D'	x·Q(x)
054	11	E'	shift from r to WR
063	15		Print HOB
080	-1		calc. Y1/3
100	13		calc. 4.1
103	11		calc. 4.0

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
000	76	LBL	Label A'.
001	16	A'	
002	43		Data unpacking:
003	43	RCL	
004	10	10	
005	55	÷	
006	43	RCL	Shift decimal by
007	02	02	log(R02) places
008	45	×	
009	5A	INT	
010	42	STO	Store remainder
011	13	13	
012	04	4	log(R02) digits
013	32	RTN	Retrieve in .xxx form
014	76	LBL	Label B'.
015	11	B'	
016	04	4	
017	44	+ × −	e^{-x}
018	22	INV	
019	23	LNX	
020	32	RTN	
021	76	LBL	Label C'.
022	12	C'	
023	05	5	
024	43	RCL	
025	10	10	
026	03	03	...log Y+1
027	55	÷	
028	01	1	
029	43	RCL	
030	43	RTN	
031	76	LBL	Label D'.
032	14	D'	
033	05	5	
034	05	5	Calculate Q(x)
035	04	4	(approximation to
036	03	3	complement of the
037	09	9	cumulative normal
038	05	5	dist.)
039	04	4	
040	00	0	
041	01	1	
042	05	5	
043	04	4	
044	01	1	
045	11	E'	
046	55	÷	
047	01	1	
048	95	=	
049	65	×	
050	44	+ −	
051	55	÷	
052	01	1	
053	95	=	
054	32	RTN	Q(x)
055	76	LBL	Label E'.
056	15	E'	
057	65	×	Used in combining
058	42	STO	algorithm.
059	12	12	$.96r_{50}$, (r_B)
060	53	(	
061	43	RCL	
062	28	28	$-r_B^2$
063	55	÷	
064	02	2	
065	01	GTO	
066	11	E'	
067	76	LBL	Label E.
068	15	E	Check and print HOB
069	00	0	
070	55	÷	
071	01	1	
072	01	1	
073	42	STO	
074	02	02	for indirect RCL (Pgm 9)
075	02	2	
076	43	3	"H"
077	32	X:T	
078	01	1	
079	43	EE	
080	03	3	
081	55	÷	
082	43	RCL	$10^3 Y^{1/3}$
083	00	00	
084	34	FIX	($R03 = Y^{-1/3}$ from Pgm 2
085	02	02	call)
086	00	0	Print HOB
087	32	RTN	
088	76	LBL	Label D.
089	14	D	
090	43	RCL	Calculate $Y^{1/3}$
091	00	00	
092	32	INV	
093	45	y^x	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
094	03	3	
095	85	=	
096	43	ENG	... $Y^{1/3}$; * HOB
097	11	11	
098	32	RTN	
099	76	LBL	Label B.
100	12	B	Opt. HOB
101	22	INV	
102	76	LBL	Label A.
103	11	A	given HOB
104	36	STF	Flag 9 up → normal
105	09	09	(i.e. 2.0)
106	23	INV	Flag 9 down → use opt.
107	36	STF	HOB
108	02	02	Initialize flag used to
109	93	.	suppress printing
110	01	1	temporarily
111	36	PGM	
112	09	09	
113	77	B*	Print Y
114	60	DP	Skip register pointer
115	32	32	to R12 = environment
116	01	1	
117	00	0	"E"
118	22	INT	
119	02	2	
120	00	0	Upper limit
121	36	PGM	
122	09	09	Print environment
123	16	A*	category
124	05	5	
125	00	0	
126	01	1	
127	00	0	
128	04	4	
129	76	FIX	
130	15	E	E
131	42	STO	
132	00	00	Number of digits for
133	02	02	data unpacking
134	85	=	
135	42	STO	Program step location
136	00	00	for packed coefficients
137	71	SBR	
138	40	IND	

STEP	CODE	KEY	COMMENTS
141	13	13	
142	42	STO	
143	13	13	Retrieve packed
144	01	1	coefficients
145	00	0	
146	22	INV	
147	76	GE	If E ≥ 18,
148	05	05	print results
149	84	84	(calculation is already
150	16	A*	complete)
151	42	STO	
152	38	38	$^{*}R$
153	03	3	
154	85	=	
155	01	1	
156	85	=	
157	43	LOG	
158	42	STO	
159	00	00	$\cdot n(1-\cdot\frac{2}{R}) = -\cdot\frac{2}{R}$
160	77	B*	$^{*}B$
161	00	0	
162	00	0	
163	01	1	
164	00	0	
165	00	00	$^{*}W = 1$ in case HOB = 0
166	85	=	
167	43	LOG	
168	42	STO	$\cdot n(1-\cdot\frac{2}{B}) = -\cdot\frac{2}{B}$
169	00	00	
170	16	A*	
171	42	STO	$-\cdot\frac{2}{R}$
172	00	00	
173	85	=	
174	43	LOG	
175	42	STO	
176	00	00	·; see Eq.5
177	85	=	
178	43	LOG	
179	76	GE	(If E=15, then skip
180	15	15	radiation contribution)
181	77	B*	$(Opt.\ HOB \cdot 10^3)^{\cdot x_D}$
182	65	×	
183	04	4	
184	00	00	
185	02	02	(Use 1 = opt. HOB)
186	02	02	
187	55	÷	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
188	32	X:T	
189	93	.	
190	01	1	Case for HOB_{OPT}=1000
191	22	INV	
192	87	EQ	
193	01	01	
194	98	98	
195	55	÷	
196	01	1	
197	92	EE	
198	03	3	
199	94	+/-	
200	65	×	
201	44	SUM	Store HOB optimum in R11
202	11	11	
203	08	08	Calculate AJVN: Print HOB
204	34	34	
205	43	ENC	HOB ↓↑ y_0
206	43	43	
207	42	STO	y_0
208	11	11	
209	33	RCL	HOB'
210	11	11	
211	33	RCL	$y^{-1/3}$ (from Pgm 2)
212	00	00	
213	85	=	
214	42	STO	H
215	00	00	
216	87	EQ	
217	04	04	If HOB=0, skip W_H, $W_.$, W_y, W
218	00	00	
219	00	0	
220	93	.	
221	01	1	
222	55	÷	
223	43	RCL	q: see Eq. 21
224	00	00	
225	65	×	
226	43	RCL	H: .9
227	00	00	
228	54	)	
229	75	−	
230	43	RCL	
231	00	00	
232	85	=	
233	87	IFF	
234	01	01	
235	39	COS	
236	55	÷	
237	93	.	Eq. 21 (cont.)
238	07	7	
239	05	5	
240	65	×	
241	02	2	q
242	93	.	
243	08	8	
244	95	=	
245	43	ENC	q + 2.8 ↓↑ 0.9H
246	24	24	
247	32	X:T	
248	06	6	
249	03	3	
250	00	0	
251	22	INV	
252	42	GE	If H ≥ 700 skip factor
253	02	02	at 161q in W_H
254	11	11	
255	87	HIF	
256	11	11	q
257	00	0	
258	01	1	
259	93	.	
260	01	1	
261	55	÷	
262	01	1	
263	75	−	W_H: see Eq. 19
264	93	.	
265	05	5	
266	75	−	
267	93	.	
268	09	9	.9H
269	65	×	
270	43	RCL	
271	00	00	
272	85	=	
273	75	−	
274	43	RCL	
275	00	00	
276	54	)	
277	85	=	
278	87	IFF	
279	01	01	
280	39	COS	
281	55	÷	
282	43	RCL	H: p: see Eq. 22
283	00	00	
284	54	)	
285	75	−	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS	STEP	CODE	KEY	COMMENTS
			Eq. 22 (cont.)				H } Eq. 12 (cont.)
			P				
			q+2.8 } Eq. 19				y_0
			W_H ; R				y_0
			If $R \neq .5$, skip W_0				y_0' in R12, y_0 in display
			H				
			W_0: see Eq. 23				
			W_0				
			$W_0 + W_H$ in R29				$.8+10^{-24}y_0^8 \cdot H$ } W_y: see Eq. 24
			H				
			y_0': see Eq. 12				
			y_0				

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
			Eq. 24 (cont.)
			$10^{-24}y_0^8 + .8$
			W_y
			$W_L + W_H + W_Y$
			Y
			WR_R: see Eq. 10
			H
			$\therefore W = \frac{WR_R}{WR_0}$
			Start of surface burst case
			a: see Eq. 16

STEP	CODE	KEY	COMMENTS
			Eq. 16 (cont.)
			y_0'
			a
			y_c: see Eq. 17
			$y_c - \log Y$
			$\exp[1.3(y-y_c)]$
			a
			$\therefore W_0$: see Eq. 14
			$\therefore W_0$

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS	STEP	CODE	KEY	COMMENTS
470	12	12	ΔW_0 ↓↑y_0'	517	33	LNX	
471	35	1/X		518	55	−	
472	65	×		519	43	RCL	
473	28	LOG		520	26	26	
474	44	SUM		521	85	+	
475	12	12	ΔW_0 - log y_0' in R12	522	48	EXC	$\frac{1}{\beta}\ln\left(\frac{WR_B}{WR_R}\right)$↓↑ $-\beta_B^2$
476	06	6		523	28	28	
477	07	7		524	55	÷	
478	00	0	m: see Eq. 13	525	43	RCL	β
479	85	+		526	26	26	
480	01	1		527	19	D'	
481	93	.		528	48	EXC	$Q\left(\frac{1}{\beta}\ln\left(\frac{WR_B}{WR_R}\right)-\frac{\beta_B^2}{\beta}\right)$↓↑ β_R^2
482	06	6		529	27	27	
483	34	FIX		530	55	÷	
484	95	=		531	32	X↑T	
485	28	LOG	m	532	02	2	
486	85	+		533	94	+/−	
487	24	CE		534	17	B'	$e^{-\frac{1}{2}\beta_R^2}$
488	19	C'		535	49	PRD	
489	43	RCL		536	27	27	
490	12	12	WR_0: see Eq. 18	537	43	RCL	
491	94	+/−		538	28	28	
492	95	=	m+m log Y - ΔW_0+log y_0'	539	55	−	
493	22	INV		540	43	RCL	
494	28	LOG		541	26	26	
495	65	×		542	19	D'	$Q\left(\frac{1}{\beta}\ln\left(\frac{WR_B}{WR_R}\right)-\beta\right)$
496	43	RCL	ΔW	543	65	×	
497	25	25	WR_R: see Eq. 10	544	43	RCL	
498	95	=		545	29	29	WR_R
499	42	STO		546	49	PRD	
500	29	29	WR_R	547	27	27	
501	36	PGM		548	93	.	
502	03	03	WR (blast): see Eq.9 (stored in R12)	549	95	=	$WR^2Q\left(\frac{1}{\beta}\ln\left(\frac{WR_B}{WR_R}\right)-\beta\right)-\beta_R^2$
503	71	SBR		550	32	X↑T	
504	99	1		551	55	−	
505	65	×		552	43	RCL	
506	93	.		553	26	26	β
507	09	9		554	75	−	$-\beta_R^2/\beta$
508	06	6	r_{50}(blast)	555	43	RCL	
509	10	E'	r_B (Eq. 7)	556	18	28	
510	10	E'	WR_B (Eq.8); r_B in R12	557	19	D'	
511	55	÷		558	48	EXC	$Q\left(-\frac{\beta_R^2}{\beta}-\frac{1}{\beta}\ln\left(\frac{WR_B}{WR_R}\right)\right)$↓↑
512	42	STO		559	28	28	
513	18	18	WR_B	560	34	+	
514	43	RCL		561	75	−	
515	29	29	WR_R	562	43	RCL	$\frac{1}{\beta}\ln\left(\frac{WR_B}{WR_R}\right)$
516	95	=		563	28	28	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
564	13	D'	$Q\left(\frac{1}{\quad}\ln\left(\frac{WR_R}{WR_B}\right) - \right)$
565	85		
566	43	RCL	W_{RB}
567	18		
568	03	W3	
569	35	+	
570	33	W^2	
571	55	=	WR^2
572	55	-	
573	53	)	
574	14	D/R	
575	43	RCL	WR $\cdot\cdot\cdot r_B$
576	12	12	
577	85	)	
578	43	RCL	
579	25	25	
580	35	+	
581	43	RCL	
582	21	21	
583	54	)	r (Eq. 2)
584	03	W3	
585	55	=	
586	35	1/x	
587	44	+ -	
588	02	2	
589	85	+	
590	01	1	
591	85	=	
592	44	STO	s (Eq. 3)
593	00	00	
594	36	R/S	Print results
595	00	0	
596	00	0	"S"
597	00	0	
598	00	0	
599	43	RCL	
600	00	00	
601	36	PGM	
602	00	0	
603	04	4	Print
604	00	0	
605	00	0	"W"
606	00	0	
607	43	RCL	
608	19	19	Environment : WR
609	44	STO	
610	12	12	
611	36	PGM	

STEP	CODE	KEY	COMMENTS
611	09	09	
612	12	B	Print WR
613	42	INV	
614	83	GTO	
615	04	04	
616	32	RTN	
617	36	R/S	Case for E=15
618	03	INT	
619	09	09	
620	06	06	
621	25	25	
622	45	CLR	When HOB_{opt} is selected
623	42	STO	
624	11	11	HOB
625	36	R/S	
626	08	08	
627	44	44	Calculate AJVN
628	43	GTO	
629	05	05	
630	01	01	
631	01	1	} V
632	02	2	
633	03	3	} Y_1
634	04	4	
635	05	5	} K
636	06	6	Class 1
637	07	7	$-H_{opt}$
638	08	8	- B
639	09	9	- R
640	32	RTN	
641	00	0	
642	01	1	
643	02	2	
644	03	3	
645	04	4	Class 2
646	05	5	
647	06	6	
648	07	7	
649	08	8	
650	09	9	
651	32	RTN	
652	00	0	
653	01	1	
654	02	2	
655	03	3	
656	04	4	Class 3
657	05	5	
658	06	6	
659	07	7	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
650	03	3	Class 4
651	03	3	
652	32	RTN	
653	00	0	
654	05	5	
655	03	3	
656	03	3	
657	04	4	
658	03	3	
659	01	1	
660	04	4	
661	03	3	
662	32	RTN	
663	01	1	Class 5
664	00	0	
665	00	0	
666	12	2	
667	04	4	
668	00	0	
669	32	RTN	
670	00	0	Class 6
671	00	0	
672	00	0	
673	00	0	
674	04	4	
675	00	0	
676	32	RTN	
677	01	1	Class 7
678	01	1	
679	04	4	
680	05	5	
681	00	0	
682	02	2	
683	32	RTN	
684	01	1	
685	02	2	
686	03	3	
687	04	4	
688	05	5	
689	06	6	
690	07	7	
691	08	8	
692	09	9	
693	10	A	
694	11	B	
695	12	C	
696	13	D	
697	14	E	
698	15	F	
699	32	RTN	
700	00	0	
701	01	1	
702	02	2	
703	02	2	
704	03	3	

STEP	CODE	KEY	COMMENTS
705	00	0	Class 8
706	00	0	
707	05	5	
708	00	0	
709	00	0	
710	32	RTN	
711	02	2	Class 9
712	01	1	
713	02	2	
714	01	1	
715	00	0	
716	00	0	
717	00	0	
718	03	3	
719	00	0	
720	32	RTN	
721	01	1	Class 10
722	00	0	
723	00	0	
724	00	0	
725	00	0	
726	00	0	
727	00	0	
728	00	0	
729	00	0	
730	32	RTN	
731	01	1	Class 11
732	00	0	
733	00	0	
734	00	0	
735	00	0	
736	00	0	
737	00	0	
738	00	0	
739	00	0	
740	32	RTN	
741	01	1	Class 12
742	00	0	
743	00	0	
744	00	0	
745	00	0	
746	00	0	
747	00	0	
748	00	0	
749	00	0	
750	32	RTN	
751	01	1	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
			Class 13
			Class 14
			Class 15
			Class 16
			Class 17

STEP	CODE	KEY	COMMENTS
			Class 18
			E=19 to b (Eq. 28)
			to a (Eq. 26)
			E=20 to b (Eq. 28)
			to a (Eq. 26)
			For environment categories 19 and 20: $y^{1/3}$;· HOB in R11
			If not flag 9, want HOB_{OPT}
			$y^{1/3}$

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
846	11	11	$1000Y^{1/3}$;· $Y^{1/3}$ in R11
847	35	1/x	
848	42	STO	
849	03	03	$Y^{-1/3}$
850	95	=	
851	42	STO	
852	33	33	HOB
853	15	E	Print HOB
854	71	SBR	
855	[illegible]	[illegible]	
856	[illegible]	[illegible]	
857	84	+/-	
858	[illegible]	E'	a: see Eq. 26
859	95	=	
860	42	STO	$\frac{8 \cdot 10^{-6}}{a}$
861	34	34	
862	[illegible]	SBR	
863	[illegible]	09	
864	44	44	
865	94	+/-	b: see Eq. 28
866	[illegible]	E'	
867	[illegible]	[illegible]	
868	[illegible]	A'	
869	[illegible]	RTN	4b
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	E	
[illegible]	[illegible]	SBR	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	E'	$(Y-b)^{p}$
[illegible]	[illegible]	=	
[illegible]	[illegible]	+	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	EE	
[illegible]	[illegible]	[illegible]	a: see Eq. 26
[illegible]	[illegible]	+	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	WR (Eq. 25)
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
891	42	STO	[illegible].3 for classes 19 and 20
892	18	18	

STEP	CODE	KEY	COMMENTS
893	92	RTN	
894	[illegible]	1	Calculation of AJVN with printing suppressed.
895	[illegible]	3	
896	[illegible]	[illegible]	
897	02	02	2 digit coefficients
898	[illegible]	[illegible]	
899	16	A'	unpack K/10
900	95	=	
901	42	STO	
902	14	14	K
903	16	A'	unpack y_1
904	85	+	
905	03	3	
906	95	=	
907	22	INV	
908	28	LOG	
909	75	-	
910	01	1	
911	08	8	
912	00	0	
913	95	=	
914	42	STO	
915	13	13	y_0 - See Eq. 11
916	86	STF	For P target
917	03	03	
918	87	IFF	
919	[illegible]	01	
920	[illegible]	[illegible]	
921	24	[illegible]	
922	86	STF	Set if flag 1 was not originally set
923	[illegible]	03	
924	[illegible]	STF	
925	[illegible]	01	Suppress printing
926	[illegible]	[illegible]	
927	[illegible]	[illegible]	
928	[illegible]	SBR	
929	44	+/-	Calculate [illegible] · R21
930	[illegible]	INV	
931	[illegible]	IFF	
932	[illegible]	[illegible]	
933	[illegible]	E	
934	[illegible]	INV	Restore original condition of flag 1
935	[illegible]	STF	
936	[illegible]	[illegible]	
937	[illegible]	[illegible]	
938	15	E	←
939	16	A'	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS	STEP	CODE	KEY	COMMENTS
440	35	+					
441	43	ENTER					
442	00	0					
443	00	0					
444	43	ENTER	H				
445	00	0					
446	00	0					
447	35	+	Subroutine used by environment categories 19 and 20.				
448	01	1					
449	00	0					
450	00	0					
451	00	0	(Next coefficient has 3 digits)				
452	00	0					
453	00	0					
454	36	ENTER					
455	42	RTN					

NOTE: Overflow from this program is in Pgm 9, steps 108 through 186, located at page 1-17.

Section 5a: Programs 5.0 and 5.1

Radius of Safety and Minimum Safe Distance Calculations.

DNA	AP-550 PROMPT AI			HTI
MINIMUM SAFE DISTANCE				
Troop Disposition	Vulnerability State	Acceptable Risk	Desired Assurance	5.n · RS,MSD
Yield (KT)	HOB (ft)	CEP (ft)	Offset, Rad. of Safety	PEH (ft)

SOURCE OF DATA:

Defense Intelligence Agency, Physical Vulnerability Handbook-Nuclear Weapons (U), AP-550-1-2-60-INT, June 1, 1969, Part III, Section C.

DESCRIPTION:

A. Objective

The objective of this set of two programs is to calculate the radius of safety (RS) and the associated minimum safe distance. The radius of safety is treated as a function of desired height of burst, yield, troop vulnerability condition, the acceptable risk category (see subsection E), and vertical delivery error, i.e., the probable error in height of burst (PEH). Considering the PEH in the radius of safety calculation requires that the user also define the confidence level he desires. For example, if the user desires a 99% assurance level value for the HOB used in the radius of safety calculation, 3.5 × PEH will be subtracted from the entered HOB. After the radius of safety calculation the program proceeds to calculate the minimum safe distance (MSD). The MSD is the sum of the RS and a buffer distance. The value of the buffer distance is a function of both a multiple of the circular error probable (CEP) and the troop disposition (see subsection E). The multiple of the CEP used is a function of the desired assurance that the acceptable weapons effects will not be exceeded.

An inversion of the above buffer distance calculation is also provided which allows the user to determine the probability that a population located some distance greater than the radius of safety from the desired ground zero will experience no greater than the acceptable weapons effects.

B. Inputs-Outputs

The two calculations comprising this program set and their necessary inputs are as follows:

Program 5.0: Radius of safety and minimum safe distance.

Inputs: Yield (KT)
HOB (ft)
CEP (ft)
PEH (ft)
Troop disposition (see subsection E)
Vulnerability condition (see subsection E)
Acceptable risk (see subsection E)
Desired Assurance Level

Program 5.1: Probability of not exceeding the acceptable weapons effects.

Inputs: CEP (ft)
Offset (ft)
Radius of safety (ft)
Troop disposition (see subsection E)

C. Limits

Yield: $0.01 \text{ KT} \leq Y \leq 30 \text{ MT}$

HOB: $\text{HOB} \geq 0$ ft

CEP: $\text{CEP} \geq 0$ ft

PEH: $\text{PEH} \geq 0$ ft

Troop disposition: 1, 2, 3, or 4
Vulnerability condition: 1, 2, or 3
Acceptable risk: 1, 2, or 3
} See subsection E

Desired assurance: $0.6 \leq P \leq 0.99$

D. Data Storage Locations, Printer Alphanumerics

The user can find the following information stored in the indicated registers (R):

Variables	Registers	Alphanumerics
Yield (KT)	R10	Y
HOB (ft)	R11	H
CEP (ft)	R12	C
Offset (ft)	R19	X
Radius of Safety (ft)	R13	RS
PEH (ft)	R14	PH
Troop disposition	R15	D
Vulnerability	R16	V
Acceptable risk	R17	R
Desired assurance	R18	P
Minimum safe distance	only in display	M
Probability of not exceeding acceptable weapons effects	only in display	P

E. Troop Disposition, Vulnerability Condition, and Degree of Risk Categories and Associated Index Numbers

1. Troop dispositions:	Indices
Linear	1
Quarter-circular	2
Semicircular	3
Circular	4

2. Vulnerability conditions:	
Unwarned exposed	1
Warned exposed	2
Warned protected	3

3. Risk categories	
Negligible	1
Moderate	2
Emergency	3

F. Additional Information

Further definition of these terms can be found in AP-550, Part III, pages 64 and 65. Pressing R/S will initiate the previously keyed-in type of calculation even if the inputs are changed.

EXAMPLE 5.0

Given the following information, calculate the radius of safety and minimum safe distance.

Yield	= 10 KT	troop disposition	= linear
HOB	= 1000 ft	vulnerability	= unwarned exposed
CEP	= 500 ft	acceptable risk	= negligible
PEH	= 100 ft	desired assurance	= 99%

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
1	Turn off - then on			0	
2	Select program 01		2nd Pgm 01	0.	
3	Enter yield (KT)	10	A	10.	
4	Enter HOB (ft)	1000	B	1000.	
5	Enter CEP (ft)	500	C	500.	
6	Enter PEH (ft)	100	E	100.	
7	Enter troop disposition	1	2nd A'	1.	
8	Enter vulnerability condition	1	2nd B'	1.	
9	Enter acceptable risk	1	2nd C'	1.	
10	Enter desired assurance	.99	2nd D'	0.99	
11	Calculate radius of safety and minimum safe distance	5.0	2nd E'		5.
					10. Y
					1000. H
					500. C
					100. PH
					1. D
					1. V
					1. R
					0.99 P
					15900. RS
				16900.	16900. M

EXAMPLE #5.1:

Given the following information, calculate the probability of not exceeding the acceptable weapons effects.

distance from troops to desired ground zero, i.e., offset = 8200 ft
radius of safety = 7000 ft
circular error probable (CEP) = 500 ft
troop disposition = semicircular

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
1	Turn off, then on			0	
2	Select program 01		2nd Pgm 01	0.	
3	Enter CEP (ft)	500	C	500.	
4	Enter offset (ft)	8200	D	8200.	
5	Enter radius of safety (ft)	7000	D	7000.	
	NOTE: Offset and radius of safety must always be entered in the above order. If one is to be changed, both values must be re-entered.				
6	Enter troop disposition (see subsection E)	2	2nd A'	2.	
7	Calculate probability of not exceeding acceptable weapons effects	5.1	2nd E'	0.993	5.1 500. C 8200. D 7000. E 2. S 0.993 E

Equations and listings for programs 5.0 and 5.1 are included with those for programs 5.2 and 5.3.

Section 5b: Programs 5.2 and 5.3

Fallout-Safe Height of Burst Calculations

DNA	AP-550 PROMPT AI				HTI
FALLOUT SAFE HEIGHT OF BURST					
			Desired Assurance	5.n → Prob., HOB	
Yield (KT)	HOB (ft)			PEH (ft)	

SOURCE OF DATA:

Defense Intelligence Agency, Physical Vulnerability Handbook - Nuclear Weapons (U), AP-550-1-2-60-INT, June 1, 1969, Part III, Section C.

DESCRIPTION:

A. Objective

The objective of this set of two programs is to calculate the minimum fallout-safe height of burst, or alternatively the probability that a selected HOB will result in an actual HOB which is fallout-safe. The calculation for minimum fallout-safe HOB is based upon fireball size and the uncertainty in actual HOB (i.e., PEH) due to delivery system characteristics; therefore, the user must specify the assurance level he desires.

To find the minimum actual HOB which will be fallout-safe, program 5.2 should be run with PEH = 0.

B. Inputs-Outputs

Program 5.2: Fallout-safe height of burst.

Inputs: Yield (KT)
PEH (ft)
Desired assurance

Program 5.3: Probability of achieving a fallout-safe HOB.

Inputs: Yield (KT)
PEH (ft)
HOB (ft)

C. Limits

Yield: 0.01KT ≤ Y ≤ 50MT
HOB: HOB ≥ 0 ft
PEH: PEH ≥ 0 ft
Desired assurance: 0.6 ≤ P ≤ 0.99

D. Data Storage Locations, Printer Alphanumerics

The user can find the following information stored in the indicated registers (R):

Variables	Registers	Alphanumerics
Yield (KT)	R10	Y
HOB (ft)	R11	H
PEH (ft)	R14	PH
Desired assurance	R18	P
Fallout-safe HOB	only in display	H
Probability that HOB is fallout-safe	only in display	P

E. Special Features

Pressing R/S will initiate the previously keyed-in type of calculation even if the inputs are changed.

EXAMPLE 5.2, 5.3

Given the following information, calculate the fallout-safe heights of burst corresponding to the two desired assurances; then invert the calculation using the HOB calculated for the second given desired assurance.

Yield = 10 KT

PEH = 100 ft

Desired assurances = 99%, 75%

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
1	Turn off - then on			0	
2	Select program 01		2nd Pgm 01	0.	
3	Enter yield (KT)	10	A	10.	
4	Enter PEH (ft)	100	E	100.	
5	Enter first desired assurance	.99	2nd D'	0.99	
6	Calculate fallout-safe HOB (ft)	5.2	2nd E'		5.2 10. Y 100. PH 0.99 P 651. H
7	Enter 2nd desired assurance	.75	2nd D'	0.75	
8	Calculate fallout-safe HOB (ft)		R/S		5.2 10. Y 100. PH 0.75 P 347. H
9	Enter HOB obtained in last calc.	347	B	347.	
10	Calc. probability of a fallout-safe HOB	5.3	2nd E'		5.3 10. Y 100. PH 347. H 0.751 P

EQUATIONS

Definitions

Y = Yield
HOB = Height of burst
CEP = Circular error probable
RS = Radius of safety
X = Offset
PEH = Probable error in height
V = Vulnerability state
R = Acceptable risk
P = Desired assurance (probability)
RS_{SR} = Slant range radius of safety
B = Buffer distance
MSD = Minimum safe distance

Calculate RS and MSD:

A slant range radius of safety is calculated as a function of Y, $RS_{SR}(Y)$, and the actual (ground range) radius of safety is calculated as:

$$RS = \left[RS_{SR}^2 - HOB'^2 \right]^{1/2}, \tag{1}$$

and the minimum safe distance is calculated as:

$$MSD = RS + B \tag{2}$$

where B and HOB' are functions of the error distributions:

$$HOB' = HOB + \frac{PEH}{1.15} \ln\left(\frac{1}{P} - 1\right) \tag{3}$$

$$B = CEP\left[b - \frac{1}{a} \ln\left(\frac{1}{P} - 1\right)\right] \tag{4}$$

where a and b are functions of troop disposition (see Table 5.1).

Calculation of RS_{SR}:

N = RS_{SR} (negligible risk)
M = RS_{SR} (moderate risk)
E = RS_{SR} (emergency risk)

For VUL = 1, (5)

$$N = \begin{cases} 7000(Y-.005)^{.13} & \text{for} \quad .01 \leq Y < 1 \\ 6250(Y+.3)^{.4} & \text{for} \quad 1 \leq Y \leq 10^5 \end{cases}$$

$$M = \begin{cases} N/1.22 & \text{for} \quad .01 \leq Y < 1 \\ N/1.2 & \text{for} \quad 1 \leq Y \leq 10^5 \end{cases}$$

$$E = \begin{cases} M/1.35 & \text{for} \quad .01 \leq Y < 1 \\ M/1.27 & \text{for} \quad 1 \leq Y \leq 10^5 \end{cases}$$

For VUL = 2,

$$N = \begin{cases} 7000(Y-.005)^{.13} & \text{for} \quad .01 \leq Y < 1 \\ 5000(Y+1.5)^{.36} & \text{for} \quad 1 \leq Y \leq 10^5 \end{cases}$$

$$M = \begin{cases} N/1.22 & \text{for} \quad .01 \leq Y < 1 \\ N/1.2 & \text{for} \quad 1 \leq Y \leq 10^5 \end{cases}$$

$$E = \begin{cases} M/1.35 & \text{for} \quad .01 \leq Y < 1 \\ M/1.27 & \text{for} \quad 1 \leq Y \leq 10^5 \end{cases}$$

For VUL = 3,

$$N = \begin{cases} 8576Y^{.2} & \text{for} \quad .01 \leq Y \leq .1 \\ 7332(Y-.05)^{.11} & \text{for} \quad .1 \leq Y \\ 3308Y^{.34} & \text{for} \quad 30 \leq Y \leq 10^5 \end{cases}$$

$$M = \begin{cases} N/1.4 & \text{for} \quad .01 \leq Y < .1 \\ 6069(Y-.075)^{.11} & \text{for} \quad .1 \leq Y < 90 \\ 2179Y^{.34} & \text{for} \quad 90 \leq Y < 300 \\ N/1.5 & \text{for} \quad 300 \leq Y \leq 10^5 \end{cases}$$

$$E = \begin{cases} M/1.38 & \text{for} \quad .01 \leq Y < .1 \\ 4341(Y-.[illegible])^{.15} & \text{for} \quad .1 \leq Y < 300 \\ M/1.43 & \text{for} \quad 300 \leq Y \leq 10^5 \end{cases}$$

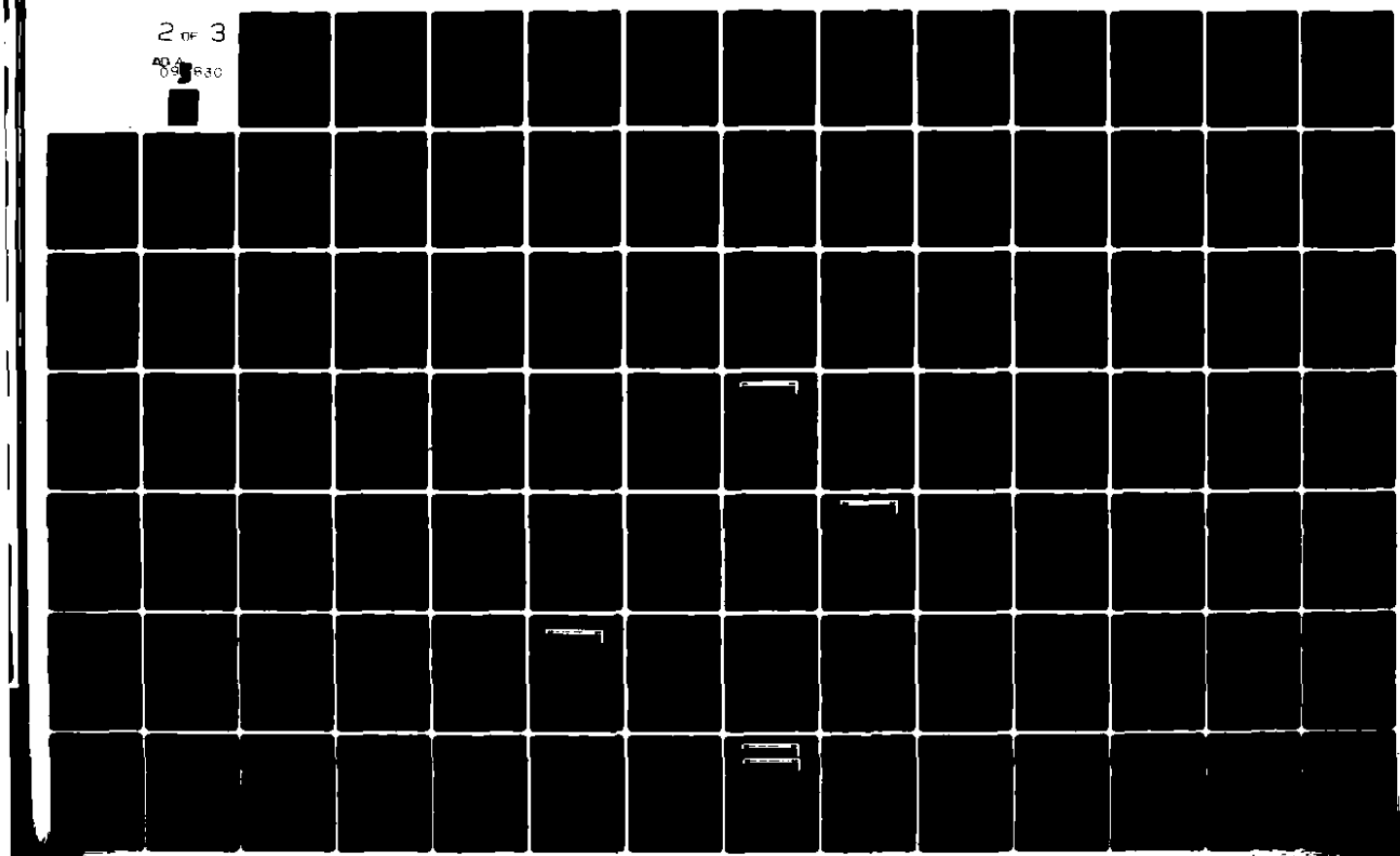
Calculation of probability of not exceeding acceptable weapons effects:

$$B = X - RS, \text{ and} \tag{6}$$

$$P = [1 + \exp a(b - B/CEP)]^{-1}, \text{ where } a \text{ and } b \text{ are given as} \tag{7}$$
in table 5.1.

AD-A095 830 HORIZONS TECHNOLOGY INC SAN DIEGO CA F/G 18/3
NUCLEAR WEAPONS TARGETING, AP-550, CROM A1, REFERENCE MANUAL.(U)
JUN 79 DNA001-78-C-0247
UNCLASSIFIED HTI-R-79-125 DNA-5277H NL

2 OF 3
AD-A095830



Calculation of the minimum HOB which has a given probability of being fallout-safe:

$$HOB = 100Y^{.4} - \frac{PEH}{1.15} \ln\left(\frac{1}{P} - 1\right) \tag{8}$$

Calculation of the probability that a given HOB is fallout-safe:

$$P = \left\{1 + \exp\left[\frac{1.15}{PEH}\left(100Y^{.4} - HOB\right)\right]\right\}^{-1} \tag{9}$$

Disposition	a	b
1	2.6	.2
2	2.6	.5
3	3	.8
4	3	1

Table 5.1

PARTITION	FLAG	COMMENTS	FLAG	COMMENTS
AUTOMATIC	07	Marks exceeded limit		

LIBRARY MODULE

CROM A-1 (Program 5)

DATA REGISTERS FOR EXAMPLE 5.2

DATA	REG.	COMMENTS
5.2	00	
137.	01	scratch
15.	02	indirect register RCL (Pgm 9)
0.	03	
0.	04	
0.	05	
0.	06	
0.	07	
0.	08	
0.	09	
10.	10	Y
0.	11	HOB
0.	12	CEP
0.	13	RS
100.	14	PEH
0.	15	Troop disposition
0.	16	Vulnerability state
0.	17	Risk
0.99	18	Assurance %
0.	19	Offset

LABELS

STEP	CODE	KEY	COMMENTS
001	81	RST	return on error
025	10	E'	input printing
031	16	A'	used in RS_{SR}
055	15	E	Print Y, PEH
072	17	B'	correct for risk cat.
085	18	C'	FSH, 50%
098	19	D'	used in RS_{SR}
111	11	A	calc. 5.0
191	97	DSZ	used in RS_{SR}
209	98	ADV	calc. RS, MSD
274	14	D	calc. 5.3
295	13	C	calc. 5.2
317	12	B	calc. 5.1

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
000	76	LBL	
001	81	RST	(Return on error)
002	92	RTN	
003	68	NOP	
004	68	NOP	
005	68	NOP	
006	03	3	
007	85	+	Coefficients for prob-
008	68	NOP	ability of damage
009	03	3	for 4 troop configur-
010	85	+	ations.
011	32	X:T	
012	32	X:T	
013	02	2	
014	85	+	
015	32	X:T	
016	32	X:T	
017	00	0	
018	95	=	
019	55	÷	
020	01	1	
021	00	0	
022	95	=	b; a is in t register
023	92	RTN	
024	76	LBL	
025	10	E'	Prints inputs which
026	36	PGM	have a lower limit of
027	09	09	0.
028	18	C'	
029	92	RTN	
030	76	LBL	
031	16	A'	Used in SR radius
032	94	+/-	of safety:
033	45	Y^x	Push operand into HIR
034	01	1	stack
035	52	EE	t = t register
036	03	3	x = display
037	94	+/-	
038	32	HIR	$\frac{-x}{1000}$
039	42	42	
040	43	RCL	
041	10	10	
042	32	HIR	$\left(\frac{-x}{1000}+Y\right)$
043	32	32	
044	53	(	
045	32	X:T	
046	55	-	

STEP	CODE	KEY	COMMENTS
047	01	1	
048	00	0	(t/100)
049	00	0	
050	95	=	$\cdots\left(\frac{-x}{1000}+Y\right)^{(t/100)}$
051	42	STO	
052	01	01	
053	92	RTN	
054	76	LBL	
055	15	E	
056	93	.	
057	00	0	
058	01	1	
059	36	PGM	Print Y
060	09	09	
061	17	B'	
062	03	3	
063	44	SUM	
064	02	02	
065	03	3	
066	03	3	Print PEH as "PH"
067	02	2	
068	03	3	
069	61	GTO	
070	10	E'	
071	76	LBL	
072	17	B'	
073	55	÷	
074	01	1	Used in RS_{SR}
075	00	0	
076	00	0	corrections
077	85	+	for moderate and
078	01	1	emergency risks
079	95	=	
080	22	INV	
081	49	PRD	
082	01	01	
083	92	RTN	
084	76	LBL	
085	18	C'	
086	01	1	
087	00	0	
088	00	0	
089	65	×	FSH, 50% probability
090	43	RCL	
091	10	10	
092	45	Y^x	
093	93	.	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
094	04	4	FSH, 50% (cont.)
095	95	=	
096	92	RTN	
097	76	LBL	
098	19	D'	
099	03	3	
100	03	3	
101	00	0	
102	08	8	Used in radius of safety, SR VUL = 3
103	65	×	
104	03	3	
105	04	4	
106	32	X↕T	
107	00	0	
108	16	A'	
109	92	RTN	
110	76	LBL	Label A. Calculation 5.0
111	11	A	
112	93	.	
113	00	0	
114	01	1	Print Y
115	36	PGM	
116	09	09	
117	17	B'	
118	02	2	
119	03	3	Print HOB
120	10	E'	
121	01	1	
122	05	5	Print CEP
123	10	E'	
124	69	OP	
125	22	22	
126	03	3	
127	03	3	Print PEH
128	02	2	
129	03	3	
130	10	E'	
131	01	1	
132	06	6	
133	32	X↕T	Print DISP
134	04	4	
135	36	PGM	
136	09	09	
137	16	A'	
138	04	4	
139	02	2	Print VUL
140	32	X↕T	
141	03	3	
142	36	PGM	Print VUL (cont.)
143	09	09	
144	16	A'	
145	03	3	
146	05	5	
147	32	X↕T	Print RISK
148	03	3	
149	36	PGM	
150	09	09	
151	16	A'	
152	71	SBR	
153	04	04	Print P_c,
154	08	08	desired probability
155	87	IFF	
156	07	07	Return on error
157	81	RST	
158	43	RCL	Calculate SR radius
159	10	10	of safety
160	28	LOG	logY
161	85	+	
162	43	RCL	
163	16	16	VUL
164	32	X↕T	
165	03	3	
166	67	EQ	
167	04	04	If VUL=3
168	80	80	
169	00	0	
170	95	=	
171	29	CP	If log Y > 0
172	77	GE	
173	04	04	(if Y ≥ 1)
174	36	36	
175	07	7	Otherwise VUL=1 or 2,
176	52	EE	
177	03	3	and Y < 1:
178	65	×	
179	01	1	
180	03	3	
181	32	X↕T	
182	05	5	(see Eq. 5)
183	16	A'	$7000(Y-.005)^{.13} = N$
184	02	2	
185	02	2	Correction for moderate risk
186	85	+	Correction for emergency risk
187	03	3	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
188	05	5	
189	65	×	
190	76	LBL	Label DSZ: distinguish
191	97	DSZ	risks
192	25	CLR	
193	43	RCL	
194	17	17	Risk
195	32	X:T	
196	01	1	
197	67	EQ	} If Risk = 1, no cor-
198	98	ADV	rection
199	82	HIR	(negligible)
200	11	11	
201	17	B'	
202	02	2	} If Risk = 2
203	67	EQ	(moderate)
204	98	ADV	
205	82	HIR	
206	12	12	Case for Risk = 3:
207	17	B'	
208	76	LBL	Label ADV
209	98	ADV	
210	71	SBR	RS_{SR} in R01
211	04	04	
212	24	24	$\frac{1.15}{PEH}$ in t register
213	25	CLR	
214	43	RCL	
215	11	11	HOB + ...
216	85	+	
217	71	SBR	
218	06	06	$\frac{PEH}{1.15} \ln\left(\frac{1}{p} - 1\right) = HOB'$
219	00	00	
220	33	X^2	(Eq. 3)
221	75	-	
222	43	RCL	RS_{SR}
223	01	01	
224	33	X^2	
225	95	=	
226	94	+/-	RS^2, Ground range
227	29	CP	(Eq. 1)
228	77	GE	
229	02	02	
230	32	32	
231	25	CLR	
232	34	fX	RS
233	32	X:T	} Print RS
234	03	3	
235	05	5	"R"
236	03	3	
237	06	6	"S"
238	98	ADV	} Print RS
239	32	X:T	
240	36	PGM	
241	09	09	
242	12	B	
243	42	STO	RS
244	13	13	
245	43	RCL	Disposition
246	15	15	
247	71	SBR	
248	03	03	Get coefficient for MSD
249	92	92	
250	32	X:T	a
251	55	÷	
252	43	RCL	
253	12	12	
254	95	=	$\frac{a}{CEP}$
255	32	X:T	b
256	65	×	x
257	43	RCL	CEP
258	12	12	
259	85	+	
260	43	RCL	RS
261	13	13	
262	75	-	
263	03	3	
264	00	0	"M"
265	71	SBR	
266	03	03	Print MSD
267	08	08	
268	32	X:T	
269	43	RCL	
270	13	13	RS→t
271	32	X:T	
272	92	RTN	MSD in display
273	76	LBL	Label D. Calculation
274	14	D	5.3
275	15	E	Print Y, PEH
276	01	1	
277	01	1	
279	42	STO	} Print H
279	02	02	
280	02	2	
281	03	3	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
282	10	E'	
283	87	IFF	Return on error
284	07	07	
285	81	RST	
286	71	SBR	
287	04	04	$100Y^{.4}$; $\frac{1.15}{PEH}$ in t reg.
288	24	24	
289	43	RCL	
290	11	11	
291	61	GTO	$100Y^{.4}$ - HOB
292	03	03	
293	74	74	Print P (Eq. 9)
294	76	LBL	Label C. Calculation 5.2
295	13	C	
296	15	E	Print Y, PEH
297	71	SBR	
298	04	04	Print P
299	08	08	
300	87	IFF	Return on error
301	07	07	
302	81	RST	
303	71	SBR	
304	04	04	$100Y^{.4} - \frac{1.15}{PEH}$ in t reg.
305	24	24	
306	02	2	"H"
307	03	3	
308	71	SBR	
309	06	06	(Eq. 8)
310	00	00	
311	36	PGM	
312	09	09	Print distance (FSH or MSD)
313	12	B	
314	98	ADV	
315	92	RTN	
316	76	LBL	Label B. Calculation 5.1
317	12	B	
318	02	2	
319	44	SUM	
320	02	02	
321	01	1	"C" Print CEP
322	05	5	
323	10	E'	
324	43	RCL	X
325	19	19	
326	32	X:T	CEP
327	65	×	
328	93	.	
329	06	6	
330	85	+	
331	43	RCL	RS
332	13	13	
333	85	+	
334	09	9	
335	52	EE	
336	09	9	
337	65	×	
338	04	4	"X"
339	04	4	
340	36	PGM	
341	09	09	
342	11	A	
343	03	3	"R"
344	05	5	
345	03	3	
346	06	6	"S"
347	10	E'	
348	69	DP	
349	22	22	
350	01	1	"D"
351	06	6	
352	32	X:T	
353	04	4	
354	36	PGM	
355	09	09	
356	16	A'	
357	87	IFF	Return on error
358	07	07	
359	81	RST	
360	71	SBR	
361	03	03	
362	92	92	b
363	75	-	
364	53	(	
365	43	RCL	
366	19	19	(X
367	75	-	-
368	43	RCL	RS)/CEP
369	13	13	
370	54	)	
371	55	÷	
372	43	RCL	
373	12	12	
374	95	=	
375	65	×	

Lower limit = .9 CEP + RS

Print offset (cont.)

Print radius of safety

Print disposition

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
376	32	X:T	$a\left(\frac{1.15}{PEH}\right.$ for calc. 5.3$\left.\right)$
377	95	=	
378	22	INV	
379	23	LNX	
380	85	+	
381	03	3	"P"
382	03	3	
383	32	X:T	
384	01	1	
385	95	=	
386	35	1/X	P (Eq. 7)
387	98	ADV	
388	36	PGM	
389	09	09	Print "P"
390	12	B	
391	92	RTN	
392	65	×	Disposition
393	02	2	
394	93	.	
395	06	6	Used for retrieval
396	32	X:T	of coefficients
397	04	4	for 4 risk
398	95	=	categories -
399	42	STO	See note on
400	01	01	coefficient
401	01	1	retrieval
402	00	0	For
403	75	-	Disp: R01:
404	53	(	1 004
405	03	3	2 008
406	83	GO*	3 012
407	01	01	4 016
408	43	RCL	P Print P
409	18	18	
410	32	X:T	
411	93	.	Print "P"
412	06	6	Low
413	85	+	
414	93	.	
415	09	9	
416	09	9	High
417	65	×	
418	03	3	
419	03	3	"p"
420	36	PGM	
421	09	09	
422	11	A	
423	92	RTN	
424	01	1	
425	93	.	
426	01	1	
427	05	5	
428	55	÷	
429	43	RCL	
430	14	14	
431	95	=	$\frac{1.15}{PEH}$
432	32	X:T	
433	18	C'	$100Y^{.4}$
434	75	-	
435	92	RTN	
436	43	RCL	Case for VUL≠3, $Y \geq 1$
437	16	16	
438	32	X:T	
439	02	2	
440	67	EQ	
441	04	04	If VUL=2
442	59	59	
443	04	4	Case for VUL=1,
444	00	0	$Y \geq 1$
445	32	X:T	
446	06	6	
447	02	2	
448	05	5	
449	00	0	$6250(Y+.3)^{.4}$
450	65	×	
451	03	3	
452	00	0	
453	00	0	
454	94	+/-	
455	16	A'	
456	61	GTO	
457	04	04	
458	72	72	
459	03	3	Case for VUL = 2, $Y \geq 1$
460	06	6	
461	32	X:T	
462	05	5	
463	52	EE	
464	03	3	
465	65	×	
466	01	1	
467	05	5	
468	00	0	
469	00	0	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
470	94	+/-	
471	16	A'	$(1.5+Y)^{.36}$ x 5000
472	02	2	
473	00	0	Corrections to negligible risk, for moderate and emergency risk
474	85	+	
475	02	2	
476	07	7	
477	65	×	
478	61	GTO	
479	97	DSZ	
480	04	4	Case for VUL=3
481	95	=	
482	22	INV	logY + 4, t reg = 3
483	77	GE	
484	05	05	
485	82	82	If Y < .1
486	75	-	
487	03	3	
488	52	EE	
489	03	3	
490	28	LOG	
491	95	=	
492	77	GE	
493	05	05	
494	73	73	If Y ≥ 300
495	85	+	
496	01	1	otherwise .1 ≤ Y ≤ 300
497	75	-	
498	53	(	
499	43	RCL	
500	17	17	
501	67	EQ	
502	05	05	If RISK = 3
503	59	59	
504	85	+	
505	01	1	
506	54	)	
507	67	EQ	
508	05	05	
509	28	28	If RISK = 2
510	00	0	
511	95	=	
512	77	GE	
513	05	05	
514	47	47	If Y ≥ 30
515	01	1	Start of Case for
516	01	1	VUL=3, RISK=1
517	32	X:T	.1 ≤ Y < 30
518	07	7	
519	03	3	
520	03	3	
521	02	2	
522	65	×	
523	05	5	
524	00	0	
525	16	A'	$(Y-.05)^{.11}$
526	61	GTO	
527	98	ADV	
528	03	3	Case for VUL=3, RISK=2
529	28	LOG	
530	95	=	
531	77	GE	
532	05	05	
533	50	50	If Y ≥ 90
534	01	1	Case for VUL=3, RISK=2,
535	01	1	.1 ≤ Y < 90
536	32	X:T	
537	06	6	
538	00	0	
539	06	6	
540	09	9	
541	65	×	
542	07	7	
543	05	5	
544	16	A'	$6069(Y-.075)^{.11}$
545	61	GTO	
546	98	ADV	
547	19	D'	$3308Y^{.34}$ Case for VUL=3; RISK=1; 30 ≤ Y < 300
548	61	GTO	
549	98	ADV	
550	02	2	Case for VUL=3; RISK=2;
551	01	1	90 ≤ Y < 300
552	07	7	
553	09	9	
554	71	SBR	
555	01	01	
556	03	03	$2179Y^{.34}$
557	61	GTO	
558	98	ADV	
559	25	CLR	Case for VUL=3; RISK=3
560	01	1	
561	05	5	
562	32	X:T	
563	04	4	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
564	03	3	
565	04	4	
566	01	1	
567	65	×	
568	05	5	
569	05	5	
570	16	A'	$4341x(Y-.055)^{.15}$
571	61	GTO	
572	98	ADV	
573	19	D'	Case for VUL=3; Y > 300
574	05	5	$3308Y^{.34}$
575	00	0	Corrections to negligible risk for moderate and emergency risk categories.
576	85	+	
577	04	4	
578	07	7	
579	65	×	
580	61	GTO	
581	97	DSZ	
582	02	2	Case for VUL=3; Y < .1
583	00	0	
584	32	X:T	
585	08	8	
586	05	5	
587	07	7	
588	06	6	
589	65	×	
590	00	0	
591	16	A'	$8576Y^{.2}$
592	04	4	Corrections to negligible risk for moderate and emergency categories.
593	00	0	
594	85	+	
595	03	3	
596	08	8	
597	65	×	
598	61	GTO	
599	97	DSZ	
600	32	X:T	$\frac{CEP}{a}$ or $\frac{PEH}{1.15}$
601	35	1/X	
602	65	×	
603	53	(	
604	43	RCL	P
605	18	18	
606	35	1/X	
607	75	-	
608	01	1	
609	54	)	
610	23	LNX	
611	95	=	$\frac{CEP}{a} \ln\left(\frac{1}{p} - 1\right)$
612	92	RTN	

Section 6: Programs 6.0 - 6.3

Probability of Damage Utilizing
Equivalent Target Areas

DNA	AP-550 PROMPT AI			HTI
PROBABILITY OF DAMAGE - EQUIVALENT TARGET AREA - VN SYSTEM				
CEP (ft)	TARGET LENGTH (ft)	TARGET WIDTH (ft)	SELECT AIMPOINT	6.n → Pd
YIELD (KT)	HOB (ft)		LENGTH VN, K	WIDTH VN, K

DNA	AP-550 PROMPT AI			HTI
PROBABILITY OF DAMAGE - ETA, CRATER RADIUS METHOD				
CEP (ft)	TARGET LENGTH (ft)	TARGET WIDTH (ft)	SELECT AIMPOINT	6.2 → Pd
YIELD (KT)	HOB (ft)	MEDIUM	LENGTH C.R.MULT.	WIDTH C.R.MULT.

DNA	AP-550 PROMPT AI			HTI
PROBABILITY OF DAMAGE - ETA, WEAPON RADII SPECIFIED				
CEP (ft)	TARGET LENGTH (ft)	TARGET WIDTH (ft)	SELECT AIMPOINT	6.3 → Pd
			LENGTH WR (ft)	WIDTH WR (ft)

SOURCE OF DATA:

Defense Intelligence Agency, Physical Vulnerability Handbook-Nuclear Weapons (U), AP-550-1-2-69-INT, 1 June 1969, Ch. 4, pages 28, 30-33, 37.

DESCRIPTION:

A. Objective

This program calculates the probability of damage to rectangular targets using the Equivalent Target Area (ETA) method. The ETA is an area such that the probability of placing the ground zero position within the area is equal to the probability of doing the desired damage to the target. Given the target dimensions, the circular error probable, CEP, and the weapon radii for both dimensions, the program will calculate the ETA dimensions and the probability of doing the desired damage.

The program sets offers four calculations. Program 6.0 uses the VN system to calculate the length and width weapon radii for P-type targets, those most sensitive to shock overpressure. Program 6.1 does the same for Q-type targets, those most sensitive

to dynamic pressure. Program 6.2 calculates the crater radius and then uses it to calculate the weapon radii. For cases when the weapon radii are known, Program 6.3 allows the user to enter these values and proceed with the probability of damage calculations. Once the weapon radii are obtained, the program uses the same calculation for the probability of damage in all four routines.

B. Inputs-Outputs

The CEP, target length, target width and aim point (1 for center of target, 2 for longer dimension edge) are entered in all four calculations. The other entries for each program are:

6.0: Yield, HOB, Length VN, Length k-factor, Width VN, Width k-factor.

6.1: Same as 6.0

6.2: Yield, HOB, Medium (1 = dry rock, 2 = wet rock, 3 = dry soil, 4 = wet soil), Length Crater Radius Multiplier, Width Crater Radius Multiplier.

6.3: Length Weapon Radius, Width Weapon Radius.

A negative HOB is interpreted as that distance below the ground. Programs 6.0, 6.1 and 6.2 calculate the weapon radii and all four programs display the probability of damage.

C. Limits

The following limits are the same for all the programs:

Yield: $0.1 \text{ KT} \leq Y \leq 30 \text{ MT}$

Length: $L \geq$ Width

Width: $W \geq 5$ ft.

Aimpoint: AP = 1 or 2

Program 6.0

VN: $0 \leq \text{AJVN} \leq 54$

k-factor: $0 \leq k \leq 9$

HOB: $0 \leq \text{HOB} \leq 2308\ Y^{1/3} \exp(-\text{AJVN}/15)$ ft.

AJVN = Adjusted Vulnerability Number (for width and length)

Program 6.1

VN: $0 \leq AJVN \leq 34$

k-factor: $0 \leq k \leq 9$

HOB: $0 \leq HOB \leq HOB_{max}(Y)^{1/3}$ ft.

where HOB_{max} is the minimum of:

$900\ Y^{1/3}$ ft.

$2308\ Y^{1/3}\ \exp(-AJVN/15)$ ft.

Program 6.2

HOB: $-200(Y)^{0.3} \leq HOB \leq 20(Y)^{0.3}$ ft.

Medium no.: M = 1,2,3,4

Crater Radius Mult.: $1 \leq$ Length CRM ≤ 3

$1 \leq$ Width CRM ≤ 3

D. Data Storage Locations, Printer Alphanumerics

The user can find the following information stored in the indicated registers (R).

Variable	Registers	Alphanumerics
Yield	R10	Y
HOB	R11	H
CEP	R15	C
Length	R16	L
Width	R17	W
Aim Point	R18	A
Width Weapon Radius	R27	WW
Length Weapon Radius	R29	LW

(continued)

Variable	Registers	Alphanumerics
For Programs 6.0 and 6.1		
Length k-factor	R13	LK
Width k-factor	R14	WK
Length VN	R19	LV
Width VN	R20	WV
For Program 6.2		
Medium	R12	M
Length CRM	R13	LM
Width CRM	R14	WM
For Program 6.3		
Length Weapon Radius	R13	LW
Width Weapon Radius	R14	WW

EXAMPLE 6.0, 6.1 (P and Q Target Options)

Calculate the probability of damage to a 500- by 50-ft bridge from the dynamic pressure (Q-type target) effect of a 0.5 KT weapon which bursts 100 ft. above the bridge. Assume the relevant quantities are:

CEP = 500 ft	Aim Point = Target Center
Length VN = 18	Width VN = 14
Length k = 9	Width k = 9

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
1	Turn off - then on			0	
2	Select program 01		2nd Pgm 01	0.	
3	Enter the target length, L(ft)	500	2nd B'	500.	
4	Enter the target width, W(ft)	50	2nd C'	50.	
5	Enter the weapon yield, Y(KT)	.5	A	0.5	
6	Enter the HOB(ft)	100	B	100.	
7	Enter the CEP(ft)	500	2nd A'	500.	
8	Enter the aim point (1 = target center, 2 = edge of longer dimension)	1	2nd D'	1.	
9	Enter the length VN, LV	18	D	18.	
10	Enter the length k factor, LK	9	D	9.	
11	Enter the width VN, WV	14	E	14.	
12	Enter the width k factor, WK	9	E	9.	
13	Calculate the probability of damage to the bridge from dynamic pressure. Note: If this were a P-type target, step 13 "Input Data" would be 6.0 and the resulting probability of damage (P) would be 0.347.	6.1	2nd E'	0.651	6.1 0.5 Y 18. LV 9. LK 14. WV 9. WK 100. H 375. LW 505. WW 500. C 500. L 50. W 1. A 0.651 P

EXAMPLE 6.2, 6.3 (Cratering and WR Input Options)

A solid arch concrete bridge 1000 ft long and 70 ft wide is to be attacked by a 10-KT weapon which will burst on contact with the bridge. The weapon, which is aimed towards the center of the target, has a CEP of 500 ft. Assuming the length and width crater radius multipliers are 1.25 and 1.5 respectively, calculate the probability of damage to the target. See AP-550, tables I-5, I-6, I-7, and I-10 for source of crater radius multipliers.

Change the length and width weapon radii to 350 ft and 300 ft and recalculate the probability of damage to the bridge.

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
1	Turn off - then on			0	
2	Select program 01.		2nd Pgm 01	0.	
3	Enter the weapon yield, Y(KT)	10	A	10.	
4	Enter the HOB(ft)	0	B	0.	
5	Enter the medium (1 = dry rock, 2 = wet rock, 3 = dry soil, 4 = wet soil)	1	C	1.	
6	Enter the target length, L(ft)	1000	2nd B'	1000.	
7	Enter the target width, W(ft)	70	2nd C'	70.	
8	Enter the weapon CEP(ft)	500	2nd A'	500.	
9	Enter the aim point (A = 1 center of target, A = 2 at longest dimension edge)	1	2nd D'	1.	
10	Enter the length multiplier, LM	1.25	D	1.25	
11	Enter the width multiplier, WM	1.5	E	1.5	
12	Calculate the probability of damage to the bridge utilizing the crater radius method.	6.2	2nd E'		6.2 10. Y 0. H 1. M 1.25 LM 1.5 WM 142. LW 171. WW 500. C 1000. L 70. W 1. A
				0.298	0.298 P

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
13	Enter the new length weapon radius, LW(ft)	350	D	350.	
14	Enter the new width weapon radius, WW(ft)	300	E	300.	
15	Calculate the probability of damage to the bridge from a weapon that produced these weapon radii.	6.3	2nd E'		6.3 350. LW 300. WW 500. C 1000. L 70. W 1. A
				0.536	0.536 P

EQUATIONS (Note all distances in feet)

Definitions

CR = Crater Radius
LM = Crater Radius Multiplier for Length
WM = Crater Radius Multiplier for Width
RL = Radius of Disruption for Length
RW = Radius of Disruption for Width
LW = Length Weapon Radius
WW = Width Weapon Radius
CEP = Circular Error Probable
$LCEP_a$ = Adjusted Circular Error Probable for Length
$WCEP_a$ = Adjusted Circular Error Probable for Width
L = Target Length
W = Target Width
LETA = Length Equivalent Target Area
WETA = Width Equivalent Target Area
AP = Aim Point (1=Center of Target, 2=Edge of Target) (dgz)
P = Probability of Damage
, , , and are intermediate calculation values

For Calculation 6.2 (CR Method):

RL = CR · LM (1)
RW = CR · WM (2)
LW = 1.1 · RL (3)
WW = 1.1 RW (4)

For calculations 6.0, 6.1 and 6.3 (The weapon radii are either calculated or entered)

RL = LW (5)
RW = WW (6)

The following 8 values are then used in the probability calculation: CEP, L, W, AP, RL, RW, WL and WW.

$LCEP_a$ $(CEP^2 + 0.125LE)^{1/2}$ (7)

$WCEP_a$ $(CEP^2 + 0.125WE)^{1/2}$ (8)

LETA L + 2RL (9)

WETA W + 2RW (10)

LETA : $LCEP_a$ (11)

WETA : $WCEP_a$ (12)

$$\gamma = (W+RW) \div WCEP_a \tag{13}$$

$$\delta = RW \div WCEP_a \tag{14}$$

Case 1: $\beta \leq 4$

$$P = \left|1 - \exp\left(-0.221\beta^2\right)\right|^{1/2} \times \left|1 - \exp\left(-0.221\alpha^2\right)\right|^{1/2} \tag{15}$$

Case 2: $\beta > 4$ and AP = 1 (center of target)

$$P = \left|1 - \exp\left(-0.221\alpha^2\right)\right|^{1/2} \tag{16}$$

Case 3: $\beta > 4$ and AP = 2 (edge of target)

$$P = \frac{\left|1 - \exp\left(-0.88\delta^2\right)\right|^{1/2} + \left|1 - \exp\left(-0.88\gamma^2\right)\right|^{1/2}}{2} \tag{17}$$

PARTITION	FLAG	COMMENTS	FLAG	COMMENTS
AUTOMATIC	07	Marks limit check error		
LIBRARY MODULE: CROM A-1 (Program 6)	09	Distinguish P-target from Q-target		

DATA REGISTERS FOR EXAMPLE 6.1

DATA	REG.	COMMENTS
6.1	00	
0.221	01	
19.	02	indirect RCL (Pgm 9)
1.259421105	03	
6.96.01130823	04	
.37255558833	05	
0.	06	
0.	07	
0.	08	
0.	09	
0.5	10	Y
100.	11	HOB
504.80142554	12	Soil medium: 1,2,3,4
3.	13	Length WR, CRM, or K
3.	14	Width WR, CRM, or K
500.	15	CEP
500.	16	Target length
50	17	Target width
1.	18	Aimpoint: 0,1
18.	19	Length VN
14.	20	Width VN
14.530138554	21	
0.	22	
0.	23	
403.5944119	24	
0.	25	
504.80142554	26	
504.80142554	27	
14.530138554	28	
4.650101033	29	
4.650101033	30	

LABELS

STEP	CODE	KEY	COMMENTS
001	43	E'	CEP_a calc.
015	42	D'	calc. eq.15-17
035	44	4	6.3 calc.
053	43	3	6.2 calc.
071	42	2	6.1 calc.
085	41	1	6.0 calc.

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
000	76	LBL	Label C'.
001	13	C'	
002	53	(	Calculation of adjusted CEP for width or length see Eqs. 7 and 8
003	53	(	
004	55	÷	
005	53	(	
006	53	(	
007	65	×	
008	43	RCL	
009	15	15	
010	53	(	
011	43	RCL	
012	54	)	
013	54	)	
014	22	RTN	
015	76	LBL	Label D'.
016	14	D'	
017	53	(	Calculation of a part of Eqs. 15, 16, or 17.
018	53	(	
019	53	(	
020	53	(	
021	43	RCL	
022	00	00	
023	54	)	
024	54	)	
025	33	X²	
026	33	X²	
027	44	SUM	
028	00	00	
029	54	)	
030	54	)	
031	34	√x	
032	54	)	
033	22	RTN	
034	76	LBL	Label D.
035	14	D	
036	53	(	*Input Weapon Radii*
037	53	(	
038	44	SUM	
039	00	00	
040	54	)	
041	04	4	"LW"
042	53	(	Print entered Length
043	53	(	Weapon Radius
044	53	(	
045	43	RCL	
046	04	04	
047	38	38	See Eq. 5
048	42	STO	R29=LW
049	29	29	
050	04	4	
051	03	3	
052	04	4	"WW"
053	03	3	Print entered
054	36	PGM	Width Weapon Radius
055	13	09	
056	13	C'	See Eq. 6
057	42	STO	R26=RW=WW
058	26	26	R27=WW
059	42	STO	
060	27	27	
061	01	1	"C"
062	05	5	
063	42	STO	Print
064	02	02	CEP
065	36	PGM	
066	03	03	
067	13	C'	
068	02	2	"L"
069	03	3	
070	13	LBL	Check and
071	43	RCL	print
072	07	7	Length
073	55	÷	
074	43	RCL	
075	12	EE	Lower Limit = W
076	09	9	Upper Limit = 9E9
077	36	PGM	
078	14	14	
079	13	C'	
080	04	4	"W"
081	03	3	
082	13	LBL	Check and
083	05	5	print W
084	36	PGM	Lower limit = 5
085	03	03	
086	13	C'	
087	01	1	"A"
088	03	3	
089	12	LBL	Check and print aim
090	12	B'	point
091	36	PGM	
092	04	04	
093	15	E'	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
094	87	IFF	If Flag 7
095	07	07	is set,
096	03	03	go to 370
097	70	70	
098	43	RCL	
099	29	29	
100	65	×	If LW x WW = 0,
101	43	RCL	
102	27	27	
103	95	=	then P = 0 and
104	29	CP	
105	67	EQ	
106	03	03	go to 362
107	62	62	
108	43	RCL	Calculate
109	29	29	$LCEP_a$
110	18	C'	See Eq. 7
111	53	(	
112	02	2	
113	65	×	Calculate
114	43	RCL	LETA
115	28	28	See Eq. 9
116	55	÷	
117	43	RCL	
118	16	16	
119	95	=	Calculate
120	32	X↑T	β
121	93	.	See Eq. 11
122	02	2	
123	02	2	ROI = 0.221
124	01	1	Put β in t reg
125	42	STO	
126	01	01	
127	04	4	If 4 ≥ β,
128	77	GE	Case 1
129	03	03	Go to Step 344
130	44	44	See Eq. 15
131	43	RCL	If Aim Point=1
132	16	16	(center of target),
133	32	X↑T	
134	01	1	Case 2
135	67	EQ	Go to Step 347
136	03	03	See Eq. 16
137	47	47	
138	93	.	Case 3
139	08	8	ROI=0.88
140	08	8	

STEP	CODE	KEY	COMMENTS
141	42	STO	
142	01	01	
143	43	RCL	Calculate
144	27	27	$WCEP_a$
145	18	C'	See Eq. 8
146	43	RCL	
147	26	26	Calculate
148	95	=	WETA
149	19	D'	See Eq. 10
150	55	÷	Calculate 1st
151	02	2	half of Eq. 17
152	85	+	
153	93	.	
154	05	5	Prepare to
155	49	PRD	calculate
156	26	26	last part
157	65	×	of Eq. 17
158	61	GTO	
159	03	03	Go to 347
160	47	47	
161	76	LBL	Label C.
162	13	C	
163	36	PGM	CR-WR
164	07	07	Call cratering
165	71	SBR	Code to check
166	99	PRT	Limits and print
167	02	2	Yield and HOB
168	07	7	
169	03	3	"LM"
170	00	0	
171	32	X↑T	
172	01	1	1=Lower Limit
173	85	+	
174	03	3	3=Upper Limit
175	36	PGM	Check and print
176	09	09	Length Multiplier
177	13	C	
178	04	4	
179	03	3	"WM"
180	03	3	
181	00	0	
182	32	X↑T	1=Lower Limit
183	01	1	
184	36	PGM	3=Upper Limit
185	09	09	Check and print
186	13	C	Width Multiplier
187	36	PGM	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
188	07	07	Call cratering
189	71	SBR	code to
190	95	=	calculate
191	79	x	crater radius
192	32	X:T	
193	65	×	
194	32	X:T	CR x WM = RW
195	43	RCL	See Eq. 2
196	14	14	
197	95	=	
198	42	STO	R26= RW
199	26	26	
200	42	STO	R27=WW
201	27	27	See Eq. 4
202	32	X:T	CR x LM = LW
203	65	×	
204	43	RCL	See Eq. 1
205	13	13	
206	65	×	
207	42	STO	R28=RL
208	28	28	
209	01	1	
210	93	.	
211	01	1	R29 = LW
212	49	PRD	See Eq. 3
213	27	27	
214	95	=	
215	42	STO	
216	29	29	Go to 321
217	98	ADV	to print
218	61	GTO	LW and WW
219	03	03	
220	21	21	
221	76	LBL	Label B.
222	12	B	Q-target WR
223	22	INV	
224	76	LBL	Label A.
225	11	A	P-target WR
226	86	STF	
227	09	09	
228	43	RCL	LK
229	13	13	
230	48	EXC	WK } put LV=R_{13}
231	14	14	LK=R_{14}
232	48	EXC	LV for Page 2
233	19	19	
234	42	STO	

STEP	CODE	KEY	COMMENTS
235	13	13	
236	93	.	
237	01	1	
238	36	PGM	
239	09	09	
240	17	B'	Check and print Y
241	02	2	
242	07	7	"L"
243	36	PGM	
244	02	02	
245	71	SBR	
246	94	+/-	Check and print LV, LK
247	82	HIR	
248	12	12	Max H for LV, LK
249	42	STO	
250	24	24	
251	36	PGM	
252	02	02	
253	71	SBR	Calculate LW
254	89	π	
255	42	STO	R28=RL=LW
256	28	28	See Eq. 5
257	42	STO	R29=LW
258	29	29	
259	43	RCL	
260	13	13	LV
261	48	EXC	
262	19	19	WK put WV=R_{13}
263	48	EXC	WK=R_{14}
264	14	14	LK
265	48	EXC	
266	20	20	WV
267	42	STO	
268	13	13	
269	43	RCL	Page calculation
270	00	00	
271	22	INV	
272	59	INT	
273	29	CP	
274	32	INV	(Flag 9 cleared by
275	87	EQ	page 2)
276	02	02	
277	80	80	
278	86	STF	Set flag 9 again for
279	09	09	P-target (6.0)
280	04	4	
281	03	3	"W"

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
282	36	PGM	Check WV, WK
283	02	02	
284	71	SBR	
285	94	+/-	
286	82	HIR	Max H for WV, WK
287	12	12	
288	32	X:T	
289	43	RCL	
290	24	24	
291	77	GE	
292	02	02	Max H=min{L-max H,
293	95	95	W-max H}
294	32	X:T	
295	00	0	
296	85	+	
297	43	RCL	
298	11	11	
299	32	X:T	
300	65	×	
301	02	2	"H"
302	03	3	
303	36	PGM	Check and print H
304	09	09	
305	11	A	
306	98	ADV	
307	36	PGM	
308	02	02	Calculate WW
309	71	SBR	
310	89	π	
311	42	STO	R26=RW=WW
312	26	26	See Eq. 6
313	42	STO	
314	27	27	
315	43	RCL	WV } Replace to
316	13	13	} original register
317	48	EXC	LK } positions
318	20	20	
319	42	STO	
320	13	13	
321	02	2	
322	07	7	
323	04	4	Print LW
324	03	3	
325	32	X:T	
326	43	RCL	
327	29	29	
328	36	PGM	

STEP	CODE	KEY	COMMENTS
329	09	09	
330	12	B	
331	04	4	
332	03	3	Print WW
333	04	4	
334	03	3	
335	32	X:T	
336	43	RCL	
337	27	27	
338	36	PGM	
339	09	09	
340	12	B	
341	61	GTO	Go to beginning of
342	00	00	calculation
343	61	61	
344	32	X:T	Begins calculation for
345	19	D'	Case 1; See Eq. 15
346	65	×	(step 345 calculates
347	53	(	the 1st half of Eq. 15)
348	43	RCL	Begins calculation for
349	27	27	2nd part of Eq. 15 or
350	18	C'	all of Eq. 16 or the
351	53	(	2nd part of Eq. 17.
352	02	2	See Eq. 8
353	65	×	Calculation of ⟩ or ⟩
354	43	RCL	see Eqns. 12 or 13
355	26	26	
356	85	+	
357	43	RCL	
358	17	17	
359	54	)	
360	54	)	
361	19	D'	Call D' to complete
362	98	ADV	calculation of P
363	32	X:T	
364	03	3	"p"
365	03	3	
366	32	X:T	Print out Probability
367	36	PGM	
368	09	09	
369	12	B	
370	92	RTN	

Section 7: Programs 7.0 - 7.4

Cratering Calculations

DNA	AP-550 PROMPT AI			HTI
CRATERING CALCULATIONS				
				7.n → CALC.
YIELD (KT)	HOB (ft)	SELECT MEDIUM	RADIUS (ft)	

SOURCES OF DATA:

1. Defense Intelligence Agency, Physical Vulnerability Handbook - Nuclear Weapons (U), AP-550-1-2-69-INT, 1 June 1969 (C Int), Part II, pages II-1 through II-8.
2. Horizons Technology, Inc., Nuclear Weapons Effects Programs, DNA-1 CROM-1, 3 November 1978, Programs 8 and A-1.

DESCRIPTION:

A. Objective

Given any two of the following three values, crater radius (R), height of burst (HOB), or weapon yield (Y), this program will calculate the third. Programs are also included that calculate the optimum HOB and corresponding crater radius given a yield, or optimum HOB and minimum yield given a crater radius.

Results are provided for four different surface medium categories:

Medium 1: Dry Rock (less than 3% moisture content)
Medium 2: Wet Rock (more than 3% moisture content)
Medium 3: Dry Soil (less than 10% moisture content)
Medium 4: Wet Soil (more than 10% moisture content)

A negative height of burst is interpreted as a distance below ground. Crater dimensions are estimated in the referenced documents within ±15%. In layered media or in the presence of an intersecting water table the accuracy is estimated to be reduced to ±25%.

B. Inputs-Outputs

The medium number is used in all five program calculations. The following other values are used in each program:

Program 7.0: Crater radius, depth and volume

Inputs: Yield (KT)
HOB (ft)

Program 7.1: Less than optimum depth of burst

Inputs: Yield (KT)
Crater radius (ft)

Program 7.2: Necessary yield

Inputs: Crater radius (ft)
Height of burst (ft)

Program 7.3: Maximum crater radius, optimum HOB

Inputs: Yield (KT)

Program 7.4: Minimum yield, optimum HOB

Inputs: Crater radius (ft)

A rough estimate of the following crater dimensions can be calculated from the output values:

Radius of the crater from the top of the lip = 1.25 R

Depth of the crater from the top of the lip = 1.25 D
(depth from surface)

Radius of the ejecta material = 2.5 R

C. Limits

Yield: $1 \text{ KT} \leq Y \leq 30 \text{ MT}$

Medium: M = 1,2,3,4

M = Medium
(1=dry rock, 2=wet rock,
3=dry soil, 4=wet soil)

For Program 7.0

HOB: $-200(Y)^{0.3} \leq \text{HOB} \leq 20(Y)^{0.3}$ ft

(a negative HOB denotes a depth of burst)

For Program 7.1

Crater radius: $0 \leq R \leq$ U.L. (Upper Limit)

where

U.L. = $151.8(Y)^{0.3}$ for dry rock
U.L. = $174.9(Y)^{0.3}$ for wet rock
U.L. = $161.7(Y)^{0.3}$ for dry soil
U.L. = $214.5(Y)^{0.3}$ for wet soil

For Program 7.2

HOB: $-3000 \leq HOB \leq 300$ ft

Crater radius: $L.L. \leq R \leq 4 \exp\left(A + .7 \ln\left|\frac{HOB}{442.2} + 1\right|\right)$ ft

where L.L. is the lower limit, and:

A = 5.77 for dry rock
A = 5.94 for wet rock
A = 5.94 for dry soil
A = 6.21 for wet soil

For HOB > 0

L.L. = 3.7

For HOB $\leq$ 0

$$L.L. = 3.7 \exp\left[B + \ln\left(\frac{-HOB}{3.3}\right)\right]$$

where

B = -1.27 for dry rock
B = -1.30 for wet rock
B = -1.73 for dry soil
B = -1.20 for wet soil

D. Special Features

The program leaves the calculator in the radian mode.

Pressing R/S will initiate the previously keyed-in type of calculation even if the inputs are changed.

E. Data Storage Locations, Printer Alphanumerics

Variables	Registers	Alphanumerics
Yield	R10	Y
HOB or optimum HOB	R11	H
Medium	R12	M
Radius	R13	R

EXAMPLE 7.0, 7.1, 7.2 (General Calculation and Inversions)

Calculate the crater radius, depth and volume produced by a weapon of yield 10 KT set 240 feet below the surface in dry rock. Then find, for the same weapon, the HOB that will produce a crater radius of 150 feet in wet soil. Finally, find the yield of a weapon which produces a 100-foot crafter radius when set 20 feet below the surface in wet rock.

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
1	Turn off - then on			0	
2	Select program 01		2nd Pgm 01	0.	
3	Enter weapon yield, Y(KT)	10	A	10.	
4	Enter HOB (ft)	-240	B	-240.	
	(Note that a negative HOB means a distance below ground)				
5	Enter the medium	1	C	1.	
	(1 = dry rock, 2 = wet rock, 3 = dry soil, 4 = wet soil)				
6	Calculate the crater radius and depth	7.0	2nd E'		7. 10. Y -240. H 1. M 301. R 173. D
7	Display the crater volume (ft^3)		2nd $\bar{x}$	3.01 02 2.462 07	
8	Enter crater radius, R(ft)	150	D	150.	
9	Enter the new medium value	4	C	4.	
10	Calculate the HOB (ft)	7.1	2nd E'		7.1 10. Y 4. M 150. R
				3.28	3.28 H

EXAMPLE 7.0, 7.1, 7.2 (cont.)

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
11	Enter new crater radius, R (ft)	100	D	100.	
12	Enter the HOB (ft)	-20	B	-20.	
13	Enter the new medium value	2	C	2.	
14	Calculate the weapon yield (KT)	7.2	2nd E'		7.2 -20. H 2. M 100. R
				0.49	0.49 Y

EXAMPLE #7.3, 7.4 (Optimized HOB Routines)

Calculate the maximum radius that a 1-KT yield bomb can produce in dry soil and the optimum HOB that the weapon should be set at to produce this radius. Compare this to the maximum radius produced by the same weapon in dry rock.

Then calculate the smallest yield that a weapon must have to produce a crater radius of 200 feet in wet soil and the optimum HOB that the weapon must be set at to produce this crater.

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
1	Turn off - then on			0	
2	Select program 01		2nd Pgm 01	0.	
3	Enter weapon yield, Y(KT)	1	A	1.	
4	Enter the medium (1 = dry rock, 2 = wet rock, 3 = dry soil, 4 = wet soil)	3	C	3.	
5	Calculate the maximum radius (ft) and the optimum HOB (ft)	7.3	2nd E'	 -158.	7.3 1. Y 3. M 162. R -158. H
6	Change the medium to dry rock	1	C	1.	
7	Repeat the same calculation		R/S	 -109.	7.3 1. Y 1. M 152. R -109. H
8	Enter the crater radius, R(ft)	200	D	200.	
9	Enter the new medium	4	C	4.	
10	Calculate the minimum yield (KT) and the optimum HOB (ft)	7.4	2nd E'	 -129.	7.4 4. M 200. R 0.792 Y -129. H

EQUATIONS

Definitions

Y = Yield (KT)
HOB_1 = Height of burst for the equivalent 1 KT explosion
HOB = Height of burst
R_1 = Crater radius for the equivalent 1 KT explosion
R = Crater radius
D_1 = Crater depth for the equivalent 1 KT explosion
D = Crater depth
V = Crater volume
OPT HOB = Optimal Height of Burst

Routine 7.0:

$$HOB_1 = \frac{HOB}{3.3Y^{0.3}} \tag{1}$$

For $HOB_1 \geq -4$

$$R_1 = 3.3(k-HOB_1)^s \exp\left|-q(k-HOB_1)-t\right|^l \tag{2}$$

$$D_1 = 3.3(k-HOB_1)^n \exp\left|-m(k-HOB_1)-p\right| \tag{3}$$

For $HOB_1 < -4$

$$R_1 = \exp\left\{c\sin\left|\left(a-b\ell n(-HOB_1)\right)^{0.15}\right| - d\right\} \tag{4}$$

$$D_1 = \exp\left\{h\sin\left|\left(f-g\ell n(-HOB_1)\right)^{0.2}\right| - j\right\}^* \tag{5}$$

$$R = R_1(Y)^{0.3} \tag{6}$$

$$D = D_1(Y)^{0.3} \tag{7}$$

$$V = \frac{\pi R^2 D}{2} \tag{8}$$

*For a Dry Soil Medium:

$$D_1 = \exp\left\{h\sin\left|\left(f-g\ell n(-HOB_1)\right)^{0.2}\right| - j\right\} \cdot 3 \tag{9}$$

The coefficients for the radius calculation are:

Coefficient	Dry Rock	Wet Rock	Dry Soil	Wet Soil
f	74.2	71.6	56.0	56.0
g	18.4	17.3	13.0	13.0
h	4.47	4.67	5.68	5.68
j	0.0	0.0	0.0	1.0
a	150.0	153.0	117.0	128.3
b	37.0	36.0	25.0	29.0
c	6.02	5.15	5.07	8.35
d	1.0	0.0	0.0	3.0
k	5.5	7.5	11.0	11.0
s	3.6	3.8	6.9	4.3
q	.342	.27	.38	.237
t	1.5	2.7	9.4	4.5
n	3.9	2.1	5.1	2.7
m	0.4	0.08	0.25	0.08
p	2.5	1.5	7.3	3.3

Routine 7.1

This routine uses the false position method to calculate the HOB given R and Y.

$$R_s = \frac{R}{3.3Y^{0.3}} \quad \text{(radius for a 1 KT explosion, in meters)} \tag{10}$$

$$H_{new}(1) = -\frac{r_1H_1 - r_2H_2}{r_1 - r_2} \quad \text{1st Iteration} \tag{11}$$

where:

for $R_s < \alpha$,	for $R_s \geq \alpha$,
$r_1 = \alpha - R_s$	$r_1 = \alpha - R_s$
$r_2 = (\delta - R_s)$	$r_2 = 2(\beta - R_s)$
$H_1 = -5$	$H_1 = \gamma$
$H_2 = 4$	$H_2 = 4$

(12)

(See table below for the coefficients α, β, γ, δ.)

H_1 and H_2 represent scaled depths of burst.

Using $H_{new}(1)$ as HOB_1, R_1 is calculated, using equation (2) for $R_s < \alpha$, and equation (4) for $R_s \geq \alpha$.

For $R_s \geq \alpha$, $r_2 = \frac{1}{2}r_2$. (13)

(This increases the accuracy of the false position routine).

$$R_{new} = \frac{R_1 \left| H_{new}(1) \right|}{3.3} - R_s \qquad (14)$$

for	for
$(R_{new} \times r_1) < 0$	$(R_{new} \times r_1) \geq 0$
$r_2 = R_{new}$	$r_1 = r_2$
$H_1 = H_{new}(1)$	$H_2 = H_1$
	$r_2 = R_{new}$
	$H_1 = H_{new}(1)$

(15)

Now a second H_{new} can be found using equation 11:

$$H_{new}(2) = \frac{r_1 H_1 - r_2 H_2}{r_1 - r_2} \qquad (16)$$

$$HOB = -3.3\ H_{new}(2)\ (Y)^{0.3} \qquad (17)$$

The coefficients for the HOB calculation are:

Coefficient	Dry Rock	Wet Rock	Dry Soil	Wet Soil
α[1]	28	32	35	35
β[2]	46	53	49	65
γ[3]	33	40	48	42
δ[4]	0	1	2	6

[1] α is the radius for HOB = -4 meters and Y = 1 KT

[2] Maximum R_1 in meters

[3] Depth of Burst for this Max R_1 in meters

[4] δ = radius for HOB = 5 meters, Y = 1 KT

Routine 7.2

This routine uses the false position method to calculate the yield from a given HOB and radius.

$$R_L = \ell n\left(\frac{R}{3.3}\right) \qquad (18)$$

$$H_m = \frac{HOB}{3.3} \qquad (19)$$

$$Y_{new}(1) = \frac{r_1 Y_1 - r_2 Y_2}{r_1 - r_2} \qquad (20)$$

where:

$$Y_1 = 10.3$$

$$r_2 = \ell nz + 3 + .7\ell n\left(1 - \frac{H_m}{134}\right) - R_L \qquad (21)$$

and

for $H_m > 0$

$$r_1 = R_L \div 2$$

$$Y_2 = \left|\ell n(H_m) - \ell n(4+Medium)\right| \div 3$$

for $H_m \leq 0$

$$r_1 = \left|\ell nz - w + \ell n(-H_m) - R_L\right| \div 2$$

$$Y_2 = \left(\ell n(-H_m) - w\right) \div 3$$

(see below for a table of coefficients w and z)

Now $Y_{new}(1)$ is substituted into equation 1 and then either equation 2 for $HOB_1 \geq -4$ or equation 4 for $HOB_1 < -4$ is calculated to produce a new:

$$R_1 \left|\exp\left|Y_{new}(1)\right|\right|$$

$$r_1 = .8r_1 \qquad (22)$$

Now an iterative routine is performed twice:

$$R_{new} = \ell n\left[\frac{R_1 \left|\exp\left|Y_{new}(i)\right|\right|}{3.3}\right] - R_L \qquad i = 1 \text{ or } 2 \qquad (23)$$

for $(R_{new} - r_1) < 0$	for $(R_{new} - r_1) \geq 0$
$r_2 = R_{new}$	$r_1 = r_2$
$Y_1 = Y_{new}(i)$	$Y_2 = Y_1$
	$r_2 = R_{new}$
	$Y_1 = Y_{new}(i)$

(24)

$$Y_{new}(i+1) = \frac{r_1 Y_1 - r_2 Y_2}{r_1 - r_2} \qquad (25)$$

when i+1 = 3 (2 iterations of equations 23-25)

then $Y = \exp\left|Y_{new}(3)\right|$ (26)

The coefficients for the yield calculation are:

Coefficient	Dry Rock	Wet Rock	Dry Soil	Wet Soil
z^1	16	19	19	25
w	4.05	4.25	4.68	4.42

[1]Radius for HOB = 0, Y = 1

Routine 7.3

The maximum radius R is:

$$R = 3.3\beta(Y)^{0.3} \qquad (27)$$

$$\text{OPT. HOB} = 3.3\gamma(Y)^{0.3} \qquad (28)$$

Routine 7.4

The minimum yield Y is:

$$Y = \left[\frac{R}{3.3\beta}\right]^{10/3} \qquad (29)$$

$$\text{OPT. HOB} = 3.3\gamma(Y)^{0.3} \qquad (30)$$

where Y is the value from equation 29.

PARTITION

AUTOMATIC

LIBRARY MODULE

CROM A-1 (Program 7)

FLAG	COMMENTS	FLAG	COMMENTS
07	Marks limit check error		
09	Set for depth calculation		

DATA REGISTERS FOR EXAMPLE 7.1

DATA	REG.	COMMENTS
7.1	00	
22.781237789	01	
2.	02	
-.9930327986	03	
2.630196229	04	
.2079703803	05	
0.	06	
0.	07	
0.	08	
0.	09	
10.	10	Y
3.28	11	HOB
4.	12	Soil medium: 1,2,3,4
150.	13	Radius
0.	14	
0.	15	
0.	16	
0.	17	
0.	18	
301.	19	
0.	20	
273308.	21	
11.	22	
0.	23	
-16.781237789	24	
.2079703803	25	
2.630196229	26	
-5.	27	

LABELS

STEP	CODE	KEY	COMMENTS
001	16	A'	Coeff. unpacker
021	92	RTN	Return
024	10	E'	Feet/Meters
031	18	C'	Retrieve HOB coeff.
038	17	B'	Retrieve coeff.
054	15	E	Yield scaling
066	95	=	R or D calc.
124	45	Y<	Y limit checks
132	99	PRT	Y, HOB, M lim.
151	47	CMS	M limit check
161	14	D	R_{max}, OPT HOB
195	66	PAU	Y_{min}, OPT HOB
236	19	D'	R_{max} or OPT HOB
256	11	A	R, D, V calc.
347	12	B	HOB calc.
426	13	C	Yield calc.

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
000	76	LBL	Label A'.
001	16	A'	Unpacker routine
002	53	(	for coefficients
003	22	INV	Display = Value in dis-
004	28	LOG	play when A' called
005	65	×	Takes
006	53	(	$\{$Fraction $\left[\frac{R23}{10^{R02}}\right]$
007	43	RCL	$\times 10^{(Display)}\}$
008	23	23	and puts it in the
009	55	÷	display
010	43	RCL	
011	02	02	
012	22	INV	Takes
013	28	LOG	integer $\left\lvert\frac{R23}{10^{R02}}\right\rvert$
014	75	-	
015	59	INT	
016	42	STO	and puts it in R23
017	23	23	
018	54	)	
019	54	)	
020	76	LBL	Label RTN
021	92	RTN	
022	92	RTN	
023	76	LBL	Label E'.
024	10	E'	
025	03	3	
026	93	.	3.3
027	03	3	
028	95	=	
029	92	RTN	
030	76	LBL	Label C'.
031	18	C'	
032	03	3	
033	08	8	Routine to retrieve
034	05	5	HOB coefficients
035	75	-	
036	08	8	
037	76	LBL	Label B'
038	17	B'	
039	65	×	General
040	43	RCL	coefficient
041	12	12	string routine
042	95	=	
043	42	STO	
044	21	21	
045	36	PGM	Pgm 9
046	09	09	SBR Ind 21 returns
047	71	SBR	with string in the
048	40	IND	display
049	21	21	
050	42	STO	Store string in R23
051	23	23	
052	92	RTN	
053	76	LBL	Label E.
054	15	E	
055	43	RCL	
056	10	10	
057	45	Y^x	$Y^{0.3}$
058	93	.	Scaling factor
059	03	3	
060	94	+/-	$R03=\frac{1}{Y^{0.3}}$
061	65	×	
062	42	STO	
063	03	03	
064	92	RTN	
065	76	LBL	Label =.
066	95	=	
067	04	4	Routine to calculate
068	32	X:T	crater radius
069	03	3	
070	42	STO	See Eq. 1
071	02	02	
072	15	E	$HOB_1=\frac{HOB}{3.3Y^{0.3}}$
073	43	RCL	
074	11	11	
075	94	+/-	
076	55	÷	
077	10	E'	
078	42	STO	$R05 = -HOB_1$
079	05	05	
080	77	GE	
081	05	05	If $-HOB_1 \geq 4$,
082	01	01	go to 501
083	69	DP	Calculation of CR for
084	32	32	$-HOB_1 < 4$
085	03	3	
086	05	5	
087	01	1	
088	75	-	Get coefficient
089	02	2	string
090	00	0	
091	17	B'	Store it in R23
092	43	RCL	
093	22	22	K

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
094	85	+	+
095	43	RCL	-HOB$_1$
096	05	05	
097	95	=	=
098	65	×	
099	32	X↕T	
100	00	0	
101	77	GE	
102	01	01	
103	19	19	
104	16	A'	Recall q or m
105	94	+/-	
106	75	-	
107	01	1	
108	16	A'	Recall t or p
109	95	=	
110	22	INV	
111	23	LNX	
112	65	×	
113	32	X↕T	
114	45	Y^x	
115	01	1	
116	16	A'	Recall s or n
117	65	×	
118	10	E'	
119	95	=	
120	42	STO	
121	04	04	Store R_1 or D_1 in R04
122	92	RTN	
123	76	LBL	Label Y^x.
124	45	Y^x	
125	99	.	Check and print Yield
126	01	1	
127	36	PGM	
128	09	09	
129	17	B'	
130	92	RTN	
131	76	LBL	Label PRT.
132	99	PRT	
133	71	SBR	Call yield
134	45	Y^x	check
135	02	2	HOB
136	00	0	
137	55	÷	Limit check
138	15	E	and print
139	32	X↕T	routine
140	01	1	

STEP	CODE	KEY	COMMENTS
141	00	0	
142	94	+/-	
143	85	+	
144	02	2	"H"
145	03	3	
146	32	X↕T	
147	36	PGM	
148	09	09	
149	13	C	
150	76	LBL	Label CMS
151	47	CMS	
152	03	3	"M"
153	00	0	
154	32	X↕T	Check and print
155	04	4	medium number
156	36	PGM	
157	09	09	
158	16	A'	
159	92	RTN	
160	76	LBL	Label D. Calculation of R_{max} and
161	14	D	OPT HOB.
162	71	SBR	Check and print
163	45	Y^x	yield
164	69	OP	
165	22	22	
166	71	SBR	Check and print medium
167	47	CMS	
168	97	IFF	If flag 7 set, go to
169	07	07	Label RTN
170	92	RTN	
171	98	ADV	
172	18	C'	Recall HOB
173	02	2	coefficients
174	42	STO	
175	02	02	
176	16	A'	
177	86	STF	See Eq. 27
178	07	07	
179	19	D'	Calculation of R_{max}
180	32	X↕T	
181	03	3	"R"
182	05	5	
183	32	X↕T	
184	36	PGM	Print radius
185	09	09	
186	12	B	
187	42	STO	R13=R

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
183	13	13	
184	55	÷	
185	04	4	
186	05	5	
187	65	×	
188	01	1	Go to D' to calculate
189	19	D'	OPT HOB
190	76	LBL	Label PAU.
191	66	PAU	Calculation of Y_{min} and
192	02	2	OPT HOB
193	44	SUM	
194	02	02	
195	71	SBR	Check and print medium
196	67	CMS	
197	03	3	"R"
198	05	5	Print radius
199	36	PGM	
200	09	09	
201	12	B	
202	43	RCL	
203	13	13	
204	87	IFF	If flag 7 set, go to
205	07	07	Label RTN
206	92	RTN	
207	18	C'	
208	02	2	
209	42	STO	Calculation of minimum
210	02	02	yield
211	16	A'	
212	43	RCL	See Eq. 29
213	13	13	
214	55	÷	
215	02	2	
216	16	A'	
217	55	÷	
218	10	E'	
219	22	INV	
220	45	YX	
221	04	4	"Y"
222	05	5	
223	32	X↑T	
224	93	.	
225	03	3	
226	95	=	
227	98	ADV	
228	36	PGM	Print
229	09	09	Yield
230	12	B	R10=Y
231	42	STO	
232	10	10	
233	76	LBL	Label D'
234	19	D'	
235	02	2	
236	16	A'	Calculation of OPT
237	55	÷	HOB or max R.
238	02	2	See Eq. 28 or 30
239	03	3	
240	32	X↑T	
241	15	E	
242	10	E'	
243	87	IFF	
244	07	07	
245	92	RTN	
246	94	+/-	Print OPT HOB
247	36	PGM	
248	09	09	
249	12	B	
250	42	STO	
251	11	11	R11 = OPT HOB
252	92	RTN	
253	76	LBL	Label A.
254	11	A	Calculation of R, D & Y
255	71	SBR	Call Y, HOB, M
256	99	PRT	
257	87	IFF	
258	07	07	If Flag 7 set,
259	92	RTN	go to RTN
260	98	ADV	
261	71	SBR	Call
262	95	=	radius calculation
263	79	R↓	Return with R_1 in R04
264	03	3	"R"
265	05	5	
266	32	X↑T	Print crater radius
267	36	PGM	
268	09	09	
269	12	B	
270	42	STO	
271	13	13	
272	86	STF	Set Flag 9
273	09	09	
274	04	4	Prepare for depth
275	01	1	calculation
276	07	7	
277	65	×	
278	43	RCL	
279	02	02	Get proper address to

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
282	75	-	calculate depth
283	07	7	
284	04	4	
285	02	2	
286	95	=	
287	48	EXC	Put address in R01
288	01	01	
289	42	STO	
290	00	00	
291	02	2	Go to depth calculation
292	71	SBR	
293	40	IND	
294	01	01	
295	43	RCL	Return with D in R04
296	12	12	
297	65	×	
298	43	RCL	If special case of
299	02	02	Eq. 9, then
300	95	=	
301	34	FX	$R_1 = \frac{R_1}{3}$
302	32	X↔T	
303	03	3	
304	32	INV	
305	67	EQ	
306	03	03	
307	10	10	
308	48	PRD	
309	03	03	Put R in t reg
310	78	Σ-	
311	32	INV	
312	56	STF	Remove flag 9
313	09	09	
314	01	1	"D"
315	05	5	
316	32	X↔T	Print depth
317	36	PGM	
318	09	09	
319	12	B	
320	65	×	Calculate volume
321	43	RCL	
322	13	13	
323	33	X²	See Eq. 8
324	65	×	
325	89	π	
326	55	÷	
327	02	2	Set up volume such
328	95	=	that pressing x̄ puts

STEP	CODE	KEY	COMMENTS
329	52	EE	volume in display
330	58	FIX	(truncate volume
331	03	03	to 3 decimal places)
332	52	EE	
333	58	FIX	
334	09	09	
335	42	STO	
336	01	01	
337	01	1	
338	48	EXC	
339	03	03	
340	32	INV	
341	48	PRD	
342	04	04	
343	43	RCL	Recall R
344	13	13	
345	92	RTN	
346	76	LBL	Label B.
347	12	B	Calculation of HOB in-
348	71	SBR	sion.
349	45	YX	Check and print Yield
350	69	OP	
351	32	32	
352	71	SBR	Check and print medium
353	47	CMS	
354	18	C'	Call string of coeffi-
355	04	4	cients
356	42	STO	
357	27	27	R27 = H_2 = 4
358	02	2	
359	42	STO	Recall
360	02	02	
361	16	A'	
362	42	STO	
363	24	24	R24 = r_1 =
364	03	3	
365	16	A'	
366	42	STO	R26 = r_2 =
367	26	26	
368	55	÷	See Eq. 12
369	15	E	
370	10	E'	
371	32	X↔T	Check limits
372	00	0	and print
373	85	+	radius
374	43	RCL	
375	13	13	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
376	32	X:T	
377	65	×	
378	03	3	"R"
379	05	5	
380	36	PGM	
381	09	09	
382	11	A	
383	87	IFF	If flag 7 set, go to Label RTN
384	07	07	
385	92	RTN	
386	48	ADV	
387	32	X:T	
388	15	E	$Y^{-0.3}$
389	43	RCL	
390	24	24	
391	32	X:T	
392	55	÷	$R_S=\left\lvert\frac{(R)}{3.3Y^{0.3}}\right\rvert$
393	10	E'	
394	42	STO	STO 01
395	01	01	If
396	77	GE	$R_S \geq \alpha$
397	06	06	
398	66	66	Go to Step 666
399	94	+/-	
400	42	STO	$r_2=-R_S$
401	26	26	
402	44	SUM	$\alpha-R_S=R24$
403	24	24	
404	00	0	
405	16	A'	
406	43	RCL	
407	23	23	$r_2=-R_S+\delta$
408	44	SUM	
409	26	26	
410	05	5	
411	94	+/-	$R25=H_1=-5$
412	42	STO	
413	25	25	
414	71	SBR	
415	07	07	$H_{new}=\frac{r_1H_1-r_2H_2}{r_1-r_2}$
416	47	47	
417	42	STO	
418	05	05	$R05=H_{new}$
419	71	SBR	Calculation of
420	00	00	Eq. 12
421	85	85	to get
422	61	GTO	$R_1\{H_{new}\}$
423	06	06	Go to 690
424	90	90	
425	76	LBL	Label C.
426	13	C	Calculation of Yield inversion
427	43	RCL	See Eq. 18
428	13	13	
429	55	÷	Calculation
430	10	E'	of R_L
431	23	LNX	See Eq. 18
432	42	STO	$R01=R_L$
433	01	01	
434	69	OP	
435	22	22	
436	03	3	
437	00	0	Limit check for HOB
438	00	0	and medium
439	65	×	
440	71	SBR	
441	01	01	See Eq. 19
442	39	39	
443	43	RCL	$H_m=\frac{HOB}{3.3}$
444	11	11	
445	55	÷	
446	10	E'	
447	42	STO	$R28=H_m$
448	28	28	
449	03	3	
450	07	7	
451	08	8	
452	85	+	
453	06	6	Get coefficient
454	17	B'	string from Pgm 9
455	55	÷	
456	01	1	
457	52	EE	
458	03	3	
459	75	-	
460	59	INT	
461	23	LNX	
462	42	STO	
463	24	24	$R24=r_1=\ell nz$
464	42	STO	$R26=r_2=\ell nz$
465	26	26	
466	22	INV	
467	23	LNX	
468	95	=	
469	65	×	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
470	01	1	
471	00	0	
472	42	STO	$R25=Y_1=10$
473	25	25	
474	94	+/-	-W
475	85	+	
476	43	RCL	
477	28	28	
478	94	+/-	
479	29	CP	If $-H_m \geq 0$
480	77	GE	
481	05	05	Go to 551
482	51	51	
483	35	CLR	
484	42	STO	$R24=r_1=0$
485	24	24	
486	43	RCL	
487	28	28	
488	23	LNX	
489	75	-	
490	53	(	$\phi = \ell n(H_m) - \ell n\left(4+\frac{\text{Medium}}{\text{No.}}\right)$
491	04	4	
492	85	+	
493	43	RCL	
494	12	12	
495	54	)	
496	23	LNX	
497	95	=	
498	61	GTO	Go to step 559
499	05	05	
500	59	59	
501	01	1	Calculation of Radius or Depth for $-HOB \geq 4$
502	06	6	
503	05	5	
504	85	+	
505	02	2	See Eqs. 4 and 5
506	02	2	
507	17	B'	Get coefficient string
508	03	3	Recall
509	16	A'	a or f
510	75	-	
511	02	2	Recall
512	16	A'	b or g
513	65	×	
514	43	RCL	$-HOB_1$
515	05	05	
516	23	LNX	
517	95	=	
518	29	CP	
519	77	GE	If
520	05	05	$a-b \times \ell n(-HOB_1)$
521	26	26	is < 0
522	00	0	
523	42	STO	R04 = 0 = R_1 or D_1
524	04	04	
525	92	RTN	RTN
526	45	YX	
527	93	.	
528	02	2	
529	87	IFF	Flag 9 set when depth
530	09	09	calculated
531	05	05	
532	36	36	
533	93	.	
534	01	1	
535	05	5	
536	95	=	
537	70	RAD	
538	38	SIN	
539	65	×	
540	01	1	Recall
541	16	A'	c or n
542	75	-	
543	03	3	Recall
544	16	A'	d or j
545	95	=	
546	22	INV	
547	23	LNX	
548	42	STO	Store R_1 or D_1
549	04	04	in R04
550	92	RTN	
551	23	LNX	Continuation of yield inversion
552	95	=	
553	44	SUM	$R24=\ell nz$
554	24	24	
555	32	X:T	$+[-w+\ell n(-H_m)]$
556	43	RCL	See Eq. 21
557	24	24	
558	32	X:T	
559	55	÷	
560	93	.	
561	03	3	
562	44	SUM	$R25=Y_1=10.3$
563	25	25	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
564	95	=	
565	42	STO	R27=Y_2
566	27	27	
567	43	RCL	$Y_2=\phi:.3$
568	28	28	for -Hm < 0 or
569	55	÷	$Y_2=\frac{[-w+\ell n(-H_m)]}{.3}$
570	01	1	
571	03	3	
572	04	4	for $-H_m \geq 0$
573	75	-	
574	01	1	
575	95	=	
576	23	LNX	
577	65	×	
578	93	.	
579	07	7	$R26=\ell nz+3+.7\left\lvert \ell n\left(\frac{H_m}{134}-1\right)\right\rvert$
580	85	+	
581	03	3	
582	95	=	
583	44	SUM	
584	26	26	
585	43	RCL	Limit check and print radius
586	13	13	
587	32	X:T	
588	22	INV	
589	23	LNX	
590	65	×	
591	03	3	
592	93	.	
593	07	7	
594	85	+	
595	43	RCL	
596	26	26	
597	22	INV	
598	23	LNX	
599	65	×	
600	04	4	
601	65	×	
602	03	3	"R"
603	05	5	
604	36	PGM	
605	09	09	
606	11	A	
607	87	IFF	If flag 7 set,
608	07	07	go to Label RTN
609	92	RTN	
610	71	SBR	

STEP	CODE	KEY	COMMENTS
611	07	07	R26=R26-R_L
612	08	08	Calculation of R_{new}
613	93	.	and Y_{new}
614	05	5	
615	49	PRD	$R24=\frac{R24-R_L}{2}$
616	24	24	
617	71	SBR	
618	07	07	
619	47	47	$Y_{new(1)}=\frac{r_1Y_1-r_2Y_2}{r_1-r_2}$
620	22	INV	
621	23	LNX	
622	42	STO	$R10=\exp(Y_{new(1)})$
623	10	10	
624	93	.	
625	08	8	See Eq. 21
626	49	PRD	R24 = .8(R24)
627	24	24	1st time through set
628	22	INV	flag 7 (i=1)
629	22	INV	2nd time through reset
630	86	STF	flag 7 (i=2)
631	07	07	
632	71	SBR	Use equations 2 or 4
633	95	=	to calculation a new
634	43	RCL	R_1 $Y_{new(i)}$
635	10	10	
636	23	LNX	
637	42	STO	
638	05	05	$R05=Y_{new(i)}$
639	79	÷	
640	32	X:T	
641	55	÷	$\ell n\left\lvert \frac{R_1 \cdot Y_{new(i)}}{3.3}\right\rvert$
642	10	E'	
643	23	LNX	
644	71	SBR	Calculation
645	07	07	of new
646	16	16	$Y_{new(i)}$
647	22	INV	
648	23	LNX	
649	42	STO	$R10=Y_{new(i)}$
650	10	10	
651	87	IFF	
652	07	07	If flag 7 is set
653	06	06	go to 629
654	29	29	
655	98	ADV	
656	32	X:T	
657	04	4	Print calculated

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
658	05	5	Yield value
659	32	X:T	
660	36	PGM	
661	09	09	
662	12	B	
663	42	STO	
664	10	10	
665	92	RTN	
666	02	2	Recall γ Continuation of HOB inversion
667	16	A'	
668	42	STO	
669	25	25	R25=γ
670	71	SBR	
671	07	07	R24=α-R_S
672	08	08	
673	02	2	R26=β-R_S
674	49	PRD	
675	26	26	R26=2(β-R_S)
676	71	SBR	
677	07	07	$H_{new}=\frac{r_1H_1-r_2H_2}{r_1-r_2}$
678	47	47	
679	42	STO	
680	05	05	R05=H_N
681	02	2	
682	22	INV	
683	49	PRD	$R24=\frac{\alpha-R_S}{2}$
684	24	24	
685	69	OP	
686	22	22	R02=R02+1
687	71	SBR	See Eq. 4
688	05	05	$R_1\{H_{new}\}$
689	01	01	
690	55	÷	$R_1\{H_{new}\}$
691	10	E'	
692	71	SBR	Set new values
693	07	07	
694	16	16	
695	55	÷	
696	02	2	
697	03	3	"H"
698	32	X:T	
699	15	E	Finished calculation
700	10	E'	Print and
701	94	+/-	store HOB
702	36	PGM	
703	09	09	
704	12	B	

STEP	CODE	KEY	COMMENTS
705	42	STO	
706	11	11	
707	92	RTN	
708	43	RCL	
709	01	01	
710	94	+/-	
711	44	SUM	R24=R24-R01
712	24	24	
713	44	SUM	R26=R26-R01
714	26	26	
715	92	RTN	
716	75	-	False position
717	43	RCL	*routine to set*
718	01	01	new iterative values
719	95	=	
720	42	STO	
721	04	04	
722	65	×	
723	43	RCL	
724	24	24	
725	95	=	
726	69	OP	
727	22	INV	
728	77	GE	
729	07	07	
730	39	39	
731	43	RCL	
732	26	26	
733	42	STO	
734	24	24	
735	43	RCL	
736	25	25	
737	42	STO	
738	27	27	
739	43	RCL	
740	04	04	
741	42	STO	
742	26	26	
743	43	RCL	
744	05	05	
745	42	STO	
746	25	25	
747	43	RCL	False position
748	24	24	calculation of new
749	65	×	intermediate value
750	43	RCL	$\frac{(R24)(R25)-(R26)(R27)}{(R24-R26)}$
751	25	25	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS	STEP	CODE	KEY	COMMENTS
752	75	-					
753	43	RCL					
754	27	27					
755	65	×					
756	43	RCL					
757	26	26					
758	95	=					
759	55	÷					
760	53	(					
761	43	RCL					
762	24	24					
763	75	-					
764	43	RCL					
765	26	26					
766	95	=					
767	92	RTN	NOTE: Overflow from this program is in Pgm 9, step 187 et seq., located at page 1-17.				

Appendix A: CROM A1 Demonstration

1 DNA AP-550 CONTROL A1 HTI 2				
DEMONSTRATION PROGRAM (RST, R/S)				
SOIL MEDIUM	WEAPON RADIUS	OFFSET	SKIP	→ START
YIELD	HOB	VN, K	ENVIRONMENT	PROBABILITY

SOURCE OF DATA:

Defense Intelligence Agency, Physical Vulnerability Handbook-Nuclear Weapons (U), AP-550-2-2-69-INT, June 1, 1969, Part IV.

DESCRIPTION:

A. Objective

The objective of this magnetic card auxiliary program is to provide a quick demonstration of the AP-550 CROM A1's calculational capabilities. The PC-100 printer must be attached for execution of this program. After program initiation, the five representative calculations given below are performed consecutively without pause.

1. Probability of damage and weapon radius to a circular normal P-target at the optimum height of burst, or if the user inputs a height of burst, probability of damage and weapon radius at a given height of burst; or the probability of damage to a circular uniform target if the user inputs a weapon radius.
2. Weapon radius for personnel targets at a specified height of burst.
3. Minimum Safe Distance for troops or, if an offset is provided, probability of not exceeding the acceptable weapons effects.
4. Crater radius at the optimum height of burst.
5. Weapon radius and probability of damage - ETA, crater radius method.

B. Inputs-Outputs

This program may be executed without entering any of the input data (see example). If the user chooses this option, the default values listed

in Table 4 will be used. These values can be changed by entering data in the appropriate override keys also listed in Table 4.

C. Limits

Limits can be found in the descriptions of the programs run.

D. Special Features

Up to two calculations can be skipped by entering their numbers on key '2nd D'. Numbers can be entered in any order. The numbering scheme is one through five, with one being the first calculation run, five the last.

Table 4. List of default values and override keys.

Input	Used in Calculations	Alpha-numeric	Default Value	Stored in Register	Override Key
Yield	1,2,3,4,5	Y	30 KT	10	Key A
Height of burst	1	H	Optimum	__*	Key B *
Vulnerability number	1	V	16	30	Key C +
k-factor	1	K	3	31	Key C +
Circular error probable	1,2,3,5	C	800	32	None
Target radius	1	T	2000	33	None
Offset (for P-target damage prob.)	1	X	800	34	None
Damage sigma	1	S	.2	35	None
Weapon radius	1	W	None	__*	Key 2nd B'*
Environment number	2	E	8	36	Key D
Height of burst	2,3	H	1600	37	None
Probable error in height	3	PH	20	38	None
Troop disposition	3	D	2	39	None
Troop vulnerability	3	V	2	40	None
Acceptable risk	3	R	3	41	None
Desired assurance	3	P	.95	42	Key E
Offset (for troop safety prob.)	3	X	None	__*	Key 2nd C' *
Soil medium	4,5	M	1	43	Key 2nd A'
Height of burst (for cratering damage prob.)	5	H	0	44	None
Length crater radius mult.	5	LC	2	45	None
Width crater radius mult.	5	WC	1.5	46	None
Length	5	L	800	47	None
Width	5	W	200	48	None
Aim point	5	A	1	49	None

* See next page for footnotes

* Keys B, 2nd B', and 2nd C' change the calculations performed as follows. A height of burst entered on key B will cause the weapon radius for the first calculation to be calculated at this height of burst rather than the optimum height of burst. A weapon radius entered on key 2nd B' will cause the weapon radius calculation to be bypassed in the first calculation. An offset entered on key 2nd C' will cause the probability of not exceeding acceptable weapon effects to be calculated rather than the minimum safe distance.

+ VN and k must both be entered, VN first, k second, both using key C.

EXAMPLE #1:

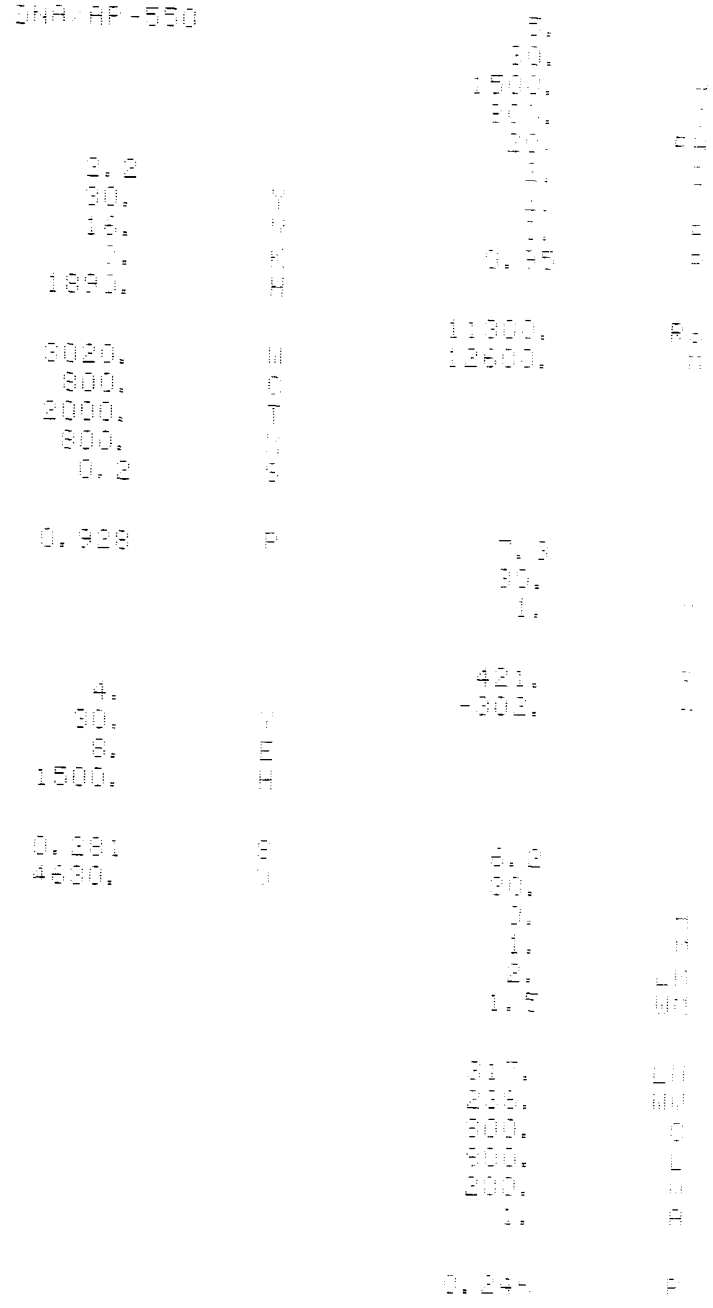
(a) Run the entire demonstration program using the default values.

(b) Run the demonstration program using a height of burst of 300 feet for the first calculation. Omit the fourth calculation.

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
1	Turn off, then on			0.	
2	Read sides 1 and 2 of card			1.,2.	
3	Initialize program (stores default values)		RST R/S	0.	
4	Run demonstration		2nd E'		see printer output (a)
5	Enter new height of burst (feet). This input overrides the optimum height of burst calculation in the 1st calculation.	300	B	300.	
6	Omit the fourth calculation. Two calculations may be skipped. Both should be entered using 2nd D'.	4	2nd D'	4.	
7	Run demonstration		2nd E'		see printer output (b)

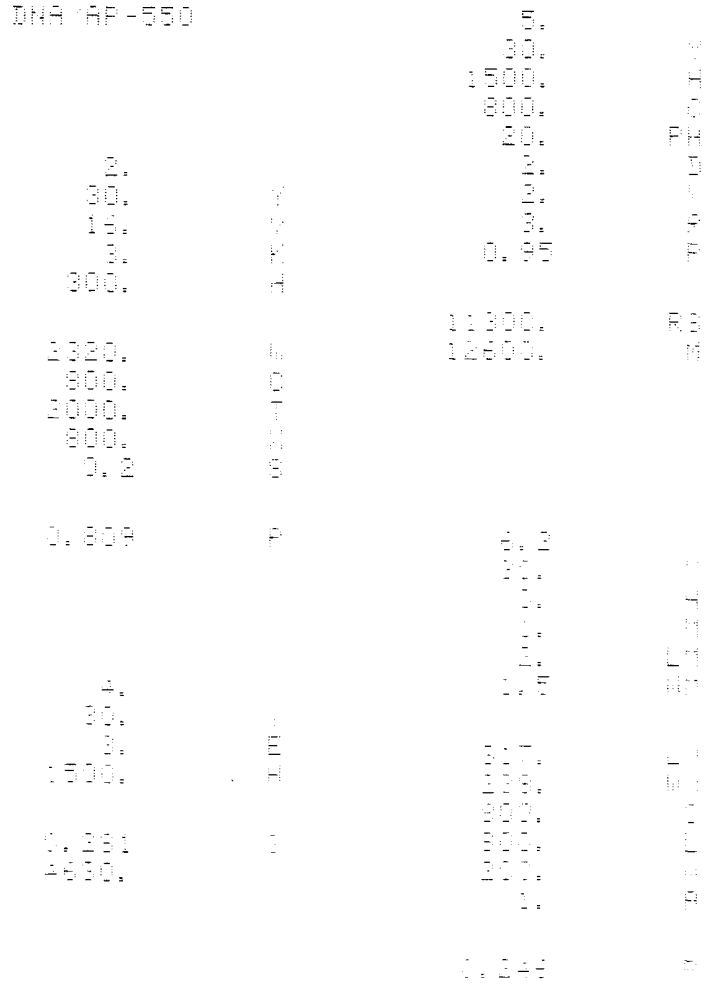
PRINTER OUTPUT FOR EXAMPLE 1:

(a)



PRINTER OUTPUT FOR EXAMPLE 1:

(b)



PARTITION	FLAG	COMMENTS	FLAG	COMMENTS
479:59	0, 1, 2, 7, 9	Used by CROM.	3	Used by control program to demonstrate different capabilities of the CROM.
AUTOMATIC	1	Suppresses CROM's printing.	4	
			5	
LIBRARY MODULE				
CROM A-1				

DATA REGISTERS FOR EXAMPLE 1

DATA	REG.	COMMENTS
[illegible]		Calc. #
[illegible]		print pointer
[illegible]		y
[illegible]		HOB
[illegible]		W, E, C, M
[illegible]		VN, RS, LM
[illegible]		k, PEH, WM
[illegible]		C, D
[illegible]		T, V, L
[illegible]		X, R, W
[illegible]		S, P, A
[illegible]		X
[illegible]		VN number
[illegible]		k factor
[illegible]		CEP
[illegible]		Target radius
[illegible]		Offset
[illegible]		Damage Sigma
[illegible]		Environment
[illegible]		HOB
[illegible]		PEH
[illegible]		Troop disposition

Registers 00 through 29 are used by the CROM Only those registers used in the control program are noted here.

LABELS			
STEP	CODE	KEY	COMMENTS
[illegible]	[illegible]	[illegible]	Initializes
[illegible]	[illegible]	[illegible]	Advances
[illegible]	[illegible]	[illegible]	Optional calculations
[illegible]	[illegible]	[illegible]	Stores Y
[illegible]	[illegible]	[illegible]	" HOB
[illegible]	[illegible]	[illegible]	" VN, k
[illegible]	[illegible]	[illegible]	" Env.
[illegible]	[illegible]	[illegible]	" Prob.
[illegible]	[illegible]	[illegible]	" Soil
[illegible]	[illegible]	[illegible]	" WR
[illegible]	[illegible]	[illegible]	" Offset
[illegible]	[illegible]	[illegible]	" Skip
[illegible]	[illegible]	[illegible]	Optional
[illegible]	[illegible]	[illegible]	Stores defaults
[illegible]	[illegible]	[illegible]	Starts demo
[illegible]	[illegible]	[illegible]	Calc. #2
[illegible]	[illegible]	[illegible]	#3
[illegible]	[illegible]	[illegible]	#4
[illegible]	[illegible]	[illegible]	#5

DATA	REG.	COMMENTS
[illegible]	40	Troop vulnerability
[illegible]	41	Acceptable risk
[illegible]	42	Desired assurance
[illegible]	43	Soil medium
[illegible]	44	HOB for ETA cratering method
[illegible]	45	Length crater radius multiplier
[illegible]	46	Width crater radius multiplier
[illegible]	47	Length
[illegible]	48	Width
[illegible]	49	Aim point
[illegible]	50	HOB for weapon radius and prob.
[illegible]	51	Weapon radius
[illegible]	52	Offset for troop safety
[illegible]	53	Omit calculation
[illegible]	54	Omit calculation

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
000	61	GTO	Go to 1/x
001	15	15	
002	76	LBL	Label CLR.
003	25	CLP	
004	25	CLP	Resets two flags
005	22	INV	used by the CROM,
006	57	ENG	stores 10 in R02
007	22	INV	for the CROM print
008	86	STF	routine.
009	01	01	
010	22	INV	
011	86	STF	
012	01	01	
013	22	INV	
014	58	FIX	
015	01	1	
016	00	0	
017	42	STO	
018	02	02	
019	76	LBL	Label ADV.
020	83	ADV	Moves paper ahead
021	83	ADV	three lines.
022	83	ADV	
023	83	ADV	
024	29	PTN	
025	76	LBL	Label RCL.
026	45	RCL	Calls the CROM weapon
027	01	1	radius and probability
028	49	PRT	of damage calculations
029	43	STO	with a user-specified
030	00	00	HOB.
031	36	PGM	
032	02	02	
033	11	A	
034	42	STO	
035	47	CMS	
036	76	LBL	Label STO.
037	11	A	
038	01	1	Calls the CROM
039	01	1	probability of damage
040	02	2	calculation with a
041	49	PRT	user-specified weapon
042	43	STO	radius
043	00	00	
044	36	PGM	
045	02	02	
046	13	C	
047	42	STO	
048	47	CMS	
049	76	LBL	Label A.
050	11	A	
051	42	STO	Stores the yield
052	10	10	
053	30	FTN	
054	76	LBL	Label B.
055	12	B	
056	42	STO	Store a HOB for the
057	50	50	weapon radius calcu-
058	86	STF	lation.
059	03	03	
060	49	PRT	Sets flag 3
061	76	LBL	Label C.
062	13	C	
063	48	EXC	Stores VN and k
064	31	31	
065	42	STO	
066	00	00	
067	43	RCL	
068	01	01	
069	49	PRT	
070	76	LBL	Label D.
071	14	D	
072	42	STO	Stores environment
073	34	FRC	
074	71	SBR	
075	76	LBL	Label E.
076	15	E	
077	42	STO	Stores probability
078	40	40	
079	71	SBR	
080	76	LBL	Label A'.
081	16	A'	
082	42	STO	Stores soil medium
083	41	41	
084	71	SBR	
085	76	LBL	Label B'.
086	17	B'	
087	42	STO	Stores weapon radius
088	42	42	for damage probability
089	71	SBR	calculation
090	76	LBL	Sets flag 4
091	18	C'	
092	42	STO	Label C'.
093	52	52	
094	71	SBR	Stores offset for
095	76	LBL	probability of

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
096	86	STF	troop safety calculation
097	05	05	Sets flag 5
098	92	RTN	
099	76	LBL	Label D'.
100	19	D'	
101	48	EXC	Stores two numbers for
102	54	54	omitting calculations.
103	42	STO	
104	53	53	
105	43	RCL	
106	54	54	
107	92	RTN	
108	76	LBL	Label X.
109	65	×	
110	86	STF	Given a user-specified
111	01	01	offset calls the CROM
112	01	1	radius of safety calc-
113	00	0	ulation, then the CROM
114	42	STO	probability of not
115	02	02	exceeding the accepta-
116	36	PGM	ble risk calculation.
117	05	05	
118	11	A	
119	71	SBR	
120	25	CLR	
121	43	RCL	
122	52	52	
123	42	STO	
124	19	19	
125	05	5	
126	93	.	
127	01	1	
128	42	STO	
129	00	00	
130	99	PRT	
131	36	PGM	
132	05	05	
133	12	B	
134	01	STO	
135	50	IEG	
136	76	LBL	Label 1/x .
137	35	1/X	
138	25	CLR	Clears pending opera-
139	03	3	tions
140	00	0	Stores 30 as the default
141	42	STO	yield,
142	10	10	16 as the default
143	01	1	VN,

STEP	CODE	KEY	COMMENTS
144	06	6	
145	42	STO	
146	30	30	
147	03	3	3 as the k-factor and
148	42	STO	the acceptable risk
149	31	31	level,
150	42	STO	
151	41	41	
152	08	8	800 as the CEP, the
153	00	0	offset (for P-target
154	00	0	damage probability),
155	42	STO	and the length (for
156	32	32	the ETA cratering
157	42	STO	probability),
158	34	34	
159	42	STO	
160	47	47	
161	01	1	1500 as the HOB
162	05	5	(for weapon radius
163	00	0	against personnel
164	00	0	targets and radius
165	42	STO	of safety),
166	37	37	
167	02	2	200 as the width (for
168	00	0	the ETA cratering
169	00	0	probability),
170	42	STO	
171	48	48	
172	02	2	
173	52	EE	2000 as the target
174	03	3	radius,
175	42	STO	
176	38	38	
177	93	.	0.2 as the damage
178	02	2	sigma,
179	42	STO	
180	39	39	
181	08	8	8 as the environment
182	42	STO	number,
183	33	33	
184	01	1	20 as the probable
185	00	0	error in height,
186	42	STO	
187	40	40	
188	02	2	2 as the troop dis-
189	42	STO	position, troop vul-
190	35	35	nerability, and length
191	42	STO	crater radius

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
192	40	.40	multiplier,
193	42	STO	
194	45	45	
195	93	.	0.95 as the desired
196	09	9	assurance,
197	05	5	
198	42	STO	
199	42	42	
200	01	1	1 as the soil medium
201	42	STO	and aim point,
202	43	43	
203	42	STO	
204	44	44	
205	01	1	1.5 as the width crater
206	93	.	radius multiplier.
207	05	5	
208	42	STO	
209	46	46	
210	09	CLR	
[illegible]	[illegible]	STO	Zeros the registers
[illegible]	50	50	for the optional
[illegible]	[illegible]	STO	inputs and the calcu-
[illegible]	51	51	lation skip numbers
[illegible]	[illegible]	STO	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	Stores 0 for the HOB
[illegible]	[illegible]	[illegible]	for cratering
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	E'	Label E'
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	INT	Initializes
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	PRGM	Prints DNA/AP-550
[illegible]	[illegible]	PRGM	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	Sees if the first
[illegible]	[illegible]	[illegible]	calculation should be
[illegible]	[illegible]	[illegible]	omitted by comparing
[illegible]	[illegible]	[illegible]	1 with the contents
237	47	CMS	of R53 and R54
238	43	RCL	
239	54	54	

STEP	CODE	KEY	COMMENTS
240	67	EQ	
241	47	CMS	
242	43	RCL	Stores HOB for the
243	50	50	user-selected HOB
244	42	STO	option
245	11	11	
246	43	RCL	Stores weapon radius
247	51	51	for the user-selected
248	42	STO	WR option
249	13	.13	
250	43	RCL	
251	30	30	Stores VN
252	42	STO	
253	13	.13	
254	43	RCL	
255	31	31	Stores k-factor
256	42	STO	
257	14	14	
258	43	RCL	
259	32	32	Stores CEP
260	42	STO	
261	15	15	
262	43	RCL	
263	33	33	Stores target radius
264	42	STO	
265	16	16	
266	43	RCL	
267	34	34	Stores offset
268	42	STO	
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	43	RCL	
[illegible]	35	35	
[illegible]	42	STO	Stores damage sigma
[illegible]	[illegible]	18	
[illegible]	[illegible]	INT	If the user input a
[illegible]	04	04	weapon radius go
[illegible]	[illegible]	STO	directly to the
[illegible]	[illegible]	INT	probability calcula-
[illegible]	[illegible]	03	tion. If the user
[illegible]	43	RCL	input an HOB use that
[illegible]	[illegible]	[illegible]	rather than the OHOB.
[illegible]	[illegible]	[illegible]	Otherwise run the
[illegible]	[illegible]	[illegible]	weapon radius and
[illegible]	[illegible]	[illegible]	probability program
[illegible]	[illegible]	RTN	at the OHOB.
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	36	PGM	
[illegible]	02	02	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
289	13	C	
289	76	LBL	Label CMs.
290	47	CMS	
291	02	2	
292	32	X≠T	Sees if the second calculation should be omitted
293	43	RCL	
294	53	53	
295	67	EQ	
296	34	FIX	
297	43	RCL	
298	54	54	
299	67	EQ	
300	34	FIX	
301	71	SBR	Initializes
302	25	CLR	
303	43	RCL	
304	03	3	Stores HOB
305	42	STO	
306	11	A	
307	43	RCL	
308	36	36	Stores environment
309	42	STO	
310	12	B	
311	04	4	
312	42	STO	
313	00	0	Runs weapon radius calculation
314	71	SBR	
315	16	PGM	
316	04	04	
317	76	LBL	Label CE.
318	14	CE	
319	03	3	Sees if the third calculation should be omitted
320	43	RCL	
321	55	55	
322	67	EQ	
323	71	SBR	
324	41	RCL	
325	52	52	
326	42	STO	
327	13	C	Stores CEP
328	12	B	
329	43	RCL	
330	38	38	

STEP	CODE	KEY	COMMENTS
331	42	STO	PEH
332	14	.	
333	43	RCL	
334	35	35	
335	42	STO	Troop disposition
336	15	.	
337	43	RCL	
338	40	40	
339	42	STO	Troop vulnerability
340	16	.	
341	43	RCL	
342	41	41	
343	42	STO	Acceptable risk
344	17	.	
345	43	RCL	
346	42	42	
347	42	STO	
348	18	18	Desired assurance
349	43	RCL	
350	37	37	
351	42	STO	HOB
352	.	.	
353	67	EQ	If the user input an offset do a probability calculation
354	15	E	
355	04	04	
356	71	SBR	
357	11	A	Initializes
358	15	E	
359	05	5	
360	04	4	
361	76	LBL	Runs minimum safe distance calculation
362	12	B	
363	05	5	
364	67	EQ	
365	71	SBR	
366	11	A	
367	76	LBL	Label DEG.
368	15	E	
369	06	6	Sees if the fourth calculation should be omitted
370	67	EQ	
371	71	SBR	
372	41	RCL	
373	53	53	
374	42	STO	
375	14	D	
376	61	GTO	
377	70	RAD	
378	71	SBR	
379	25	CLR	Initializes

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
394	43	RCL	
395	43	43	
396	42	STO	Stores soil medium
397	12	12	
398	01	1	
399	48	*	
400	03	3	
401	42	STO	
402	00	00	Runs cratering calcu-
403	94	PRT	lation
404	36	PGM	
405	07	07	
406	14	D	
407	76	LBL	Label RAD.
408	70	RAD	
409	05	5	Sees if fifth calcula-
410	33	X≠T	tion should be omitted
411	43	RCL	
412	53	53	
413	57	E0	
414	40	ADV	
415	43	RCL	
416	54	54	
417	57	E0	
418	30	ADV	
419	71	SBR	
420	35	CLR	Initializes
421	43	RCL	
422	43	43	
423	42	STO	Stores soil medium
424	12	12	
425	43	RCL	
426	45	45	
427	42	STO	Length crater radius
428	13	13	multiplier
429	43	RCL	
430	46	46	
431	42	STO	Width crater radius
432	14	14	multiplier
433	43	RCL	
434	15	15	
435	42	STO	CEP
436	15	15	
437	43	RCL	
438	16	16	Target length
439	43	RCL	

STEP	CODE	KEY	COMMENTS
440	48	48	
441	42	STO	Target width
442	17	17	
443	43	RCL	
444	49	49	
445	42	STO	Aim
446	18	18	
447	43	RCL	
448	44	44	
449	42	STO	HOB
450	11	11	
451	00	0	
452	32	X:T	
453	00	0	
454	42	STO	
455	00	00	
456	94	PRT	Runs ETA cratering
457	36	PGM	probability calcula-
458	08	08	tion
459	43	RCL	
460	53	53	
461	42	STO	
462	00	00	

Appendix B: Iterations I and II

1 DNA AP-550 CONTROL A1 HTI 1				
ITERATIONS I (Pgm. 01, Input; RST, Input, Run)				
Δx MULT.?	Δx MULT.?	Δx MULT.?	Δx MULT.?	n.n → CALC
REG_A; x_f; Δx	REG_B; x_f; Δx	REG_C; x_f; Δx	REG_D; x_f; Δx	LOOPS

DESCRIPTION:

A. Objective

This control program provides an automated way of doing parametric studies using the programs in the CROM. Input variables may be incremented by some specified amount over any desired range, with the CROM carrying out the calculation anew for each incremented input value. Each calculation run may be set to treat as many as four variables parametrically.

With this control card, Iterations I, each parameterized input variable may be stepped either by adding an amount Δx for each calculation or by multiplying the value by a factor Δx each time, as the user wishes.

The Iterations II control program operates similarly but steps through a set of values which are explicitly entered, but which, therefore, need not vary by any fixed increment.

B. Inputs

Initial inputs (i.e., for the first of the series of calculations to be run) are entered as they are normally done, through Pgm 01, following the procedures set forth for the particular calculation in the main body of this document.

Next is entered the number of variables to be parameterized (spoken of as the number of iteration "loops"). Then, for each such variable, the following are entered: (a) the register number storing its value, (b) the maximum value, x_f, to be used for that variable in the iterations, (c) the amount, Δx, of the increment to be used, and if appropriate, (d) the choice that the increment Δx multiply the previous value rather than be added to it.

C. General Instructions for Data Entry

1. Press 2nd Pgm 01.
2. Enter initial inputs for desired calculation, following format of the particular CROM program.
3. Press RST.
4. Enter number of loops desired (i.e., number of parameters to be varied) with key E.
5. For the first variable to be parameterized, enter with key A, in order:
   a. Its storage register number, (R_A) (see Fig. 2),
   b. The maximum value to be accepted, (x_f), and
   c. The increment to be applied (Δx).
   If Δx is to be applied as a multiplier (not added), press 2nd A'.
6. Repeat step 5 for successive variables using keys B and 2nd B', C and 2nd C', etc.
7. To start, enter calculation number (n.n) with key 2nd E', exactly as is done in starting this calculation when using the CROM directly.

D. Special Features

All values, REG_i, x_f, and Δx are retained after the program has been run, and do not need to be re-entered unless they are to be changed. The number of loops desired (key E) may be changed at any time.

E. Data Storage Locations

Initial values for the various parameters are stored according to the CROM's universal input routine (Pgm 01) format. The relationship between keys and storage register numbers is shown in Fig. 2.

A' R15	B' R16	C' R17	D' R18	
A R10	B R11	C R12	D R19,R13	E R20,R14

Figure 2. Register numbers corresponding to input keys of the CROM universal input routine.

Keys D and E sometimes accept a single input (e.g., crater radius), sometimes a dual input (e.g., VN and k). If two inputs are needed, the values will be stored at the respective register numbers shown. As an example, if VN and k were entered at key D, VN would be stored in R19, k in R13. However, if only one input is entered with key D (or E), the register number corresponding to that input is the one underlined (for key D, R13; for key E, R14).

EXAMPLE #1:

Calculate the weapon radii for yields .1, 1, 10 and 100 KT for the first three environment categories of the personnel vulnerability code, for both the surface burst case and the optimum height of burst cases.

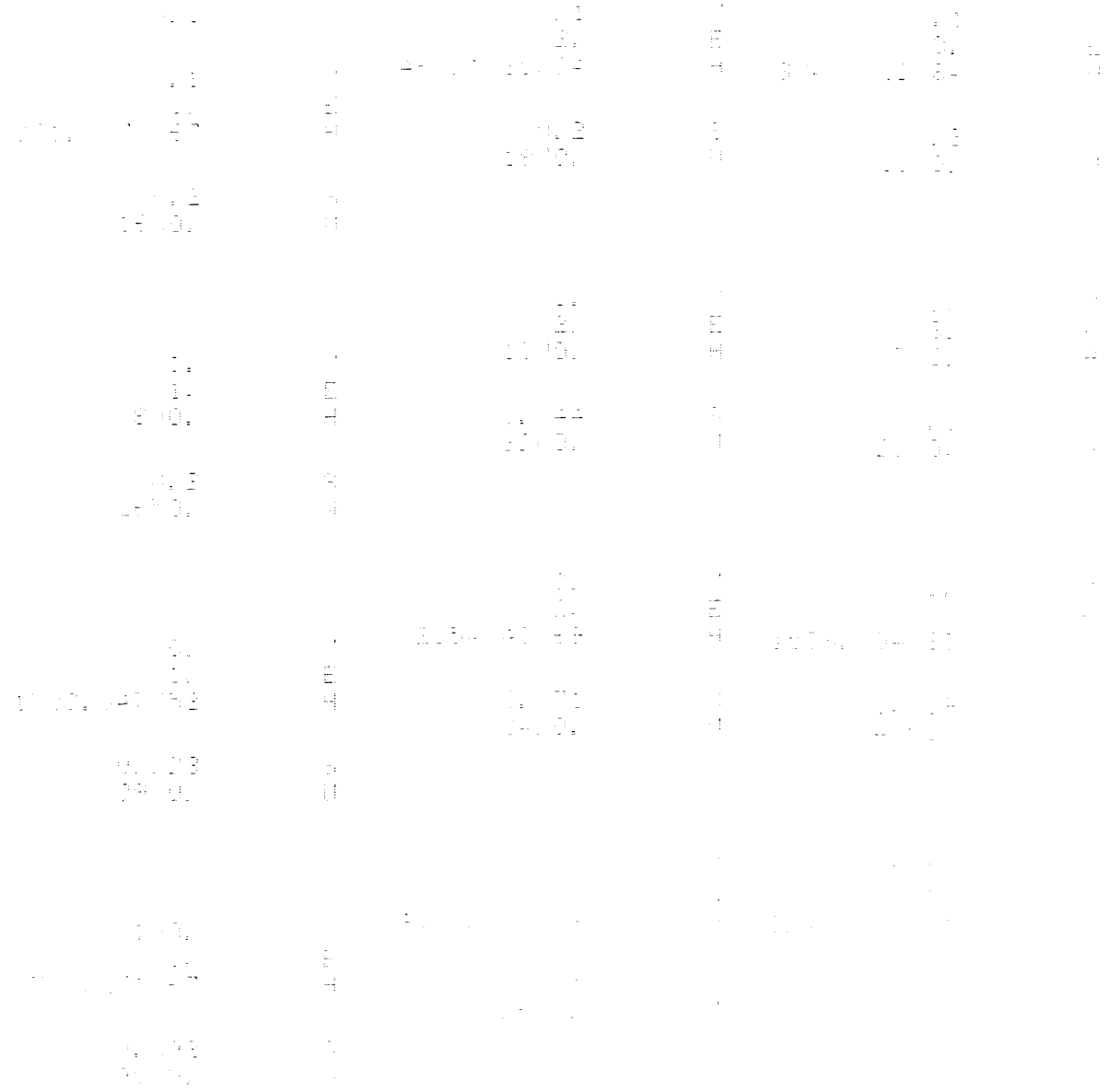
NOTES: 1. All initial values are entered through the universal input routine.

2. All product options are removed when RST is pressed. That is, after RST, all 'x's will be added (not multiplied) unless the 2nd A', 2nd B' etc., keys are again pressed.

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
1	Turn off, then on			0	
2	Read either side of Iterations I card			1.	
3	Prepare to enter initial values (per universal input routine)		2nd Pgm 01	1.	
4	Enter lowest yield (KT)	1	A	0.1	
5	Enter height of burst	0	B	0.	
6	Enter first environment category	1	C	1.	
7	Return to Iterations program		RST	1.	
8	Enter number of loops desired	2	E	2.	
9	Enter register for yield (R10) (see Fig. 1) as first incrementing register	10	A	10.	
10	Enter largest desired value for yield	100	A	100.	
11	Enter increment in yield	10	A	10.	
12	Select multiplying option for first (yield) loop		2nd A'	10.	
13	Enter register for environment categories as second incrementing loop (i.e., REG_B)	12	B	12.	
14	Enter largest desired value for environment category	3	B	3.	
15	Enter increment to environment category	1	B	1.	
16	Initiate run for surface burst case	4	2nd E'	0.	see printer output
17	Initiate run for the optimum HOB case	4.1	2nd E'	0.	see printer output

PRINTER OUTPUT FOR EXAMPLE #1, STEP 16

PRINTER OUTPUT FOR EXAMPLE #1, STEP 17



PARTITION	FLAG	COMMENTS	FLAG	COMMENTS
239.89 AUTOMATIC	0,1,2,7,9 3-6	Used by CROM. Product options		

LIBRARY MODULE: CROM A-1

DATA REGISTERS FOR EXAMPLE 1

DATA	REG.	COMMENTS	LABELS STEP	CODE	KEY	COMMENTS
		Program n.m				Set up pointer registers
		Used by CROM				Stack manipulation
						Enter initial, final, and increment values.
		Pointer registers				Number of loops
						Initiate calc.
		Universal input routine registers				Set option for multiplication into registers.
		Used by CROM				
		Pointers to registers to increment				
		Final values of incremented parameters				

DATA	REG.	COMMENTS
[illegible]	[illegible]	Increment values of parameters to increment
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	Temporary storage used by Program 0.
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	
0.	51	
0.	52	
0.	53	
0.	54	
0.	55	
0.	56	
0.	57	
0.	58	
0.	59	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
			Label DS7.
			R6=30+ ⎫ ⎬ =: 0 for LBL A, 1 for LBL B, 2 for LBL C, 3 for LBL D
			R7=34+ ⎭
			R8=38+ ⎭ 0 in recursions
			Label R/S.
			⎫ ⎬ Stack manipulation
			⎭
			Label A.
			A three-register stack:
045			x:'R30:'R34:'R38

STEP	CODE	KEY	COMMENTS
			Label B.
			Stack:
			x:'R31:'R35:'R39
			Label C.
			Stack:
			x:'R32:'R36:'R40
			Label D.
			Stack:
			x:'R33:'R37:'R41
			Label E.
			Enter loop
			Label E'.
			n.m

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
094	30	30	Copy initial values into registers 42-45
095	42	STO	
096	00	42	
097	30	FC?	
098	01	01	
099	42	STO	
100	00	43	
101	30	FC?	
102	01	01	
103	42	STO	
104	00	44	
105	30	FC?	
106	01	01	
107	42	STO	
108	00	45	
109	36	STF	
110	00	00	
111	31	SBR	Sum Σx_i
112	07	07	
113	42	STO	
114	00	09	
115	32	INV	
116	36	STF	
117	00	00	
118	31	SBR	If appropriate flag, PROD x
119	07	07	
120	30	FC?	
121	01	01	
122	01	RCL	x_i
123	00	00	
124	01	RCL	x_{f_i}
125	09	09	If $x_i = x_{f_i}$
126	30	FC?	
127	01	01	
128	01	RCL	Set $x_i = x_i$ (initial)
129	00	00	
130	36	STF	
131	00	00	
132	31	SBR	
133	07	07	
134	30	FC?	
135	01	01	
136	01	RCL	
137	00	00	
138	36	STF	
139	00	00	
140	31	SBR	
141	42	STO	Start of parameter manipulation
142	00	11	
143	30	FC?	
144	01	01	
145	42	STO	
146	00	01	
147	30	FC?	Set up for flg IND
148	01	01	
149	00		
150	00		
151	00		
152	00		
153	42	STO	
154	00	11	
155	30	FC?	
156	01	01	
157	00		
158	31	SBR	Sum Σx_i
159	07	07	
160	42	STO	
161	00	11	
162	32	INV	
163	36	STF	
164	00	00	
165	31	SBR	If appropriate flag, PROD x
166	07	07	
167	30	FC?	
168	01	01	
169	01	RCL	x_i
170	00	00	
171	01	RCL	x_{f_i}
172	09	09	If $x_i = x_{f_i}$
173	30	FC?	
174	01	01	
175	01	RCL	Set $x_i = x_i$ (initial)
176	00	00	
177	36	STF	
178	00	00	
179	31	SBR	
180	07	07	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS	STEP	CODE	KEY	COMMENTS
			If not end of loop, continue calculation				
			If end of loop, print "END"				
			Label A'. Set flag to multiply 'x for REG_A				
			Label B'. Set flag to multiply 'x for REG_B				
			Label C'. Set flag to multiply 'x for REG_C				
			Label D'. Set flag to multiply 'x for REG_D				

1a DNA AP-550 CONTROL A1 HTI 1b				
ITERATIONS II (1a RST, R/S, Input; 1b, RUN)				
R15	R16	R17	R18	n.n → CALC.
R10	R11	R12	R19, R13	R20, R14

DESCRIPTION:

A. Objective

This magnetic card program also provides for multiple calculations, varying selected inputs. This program more closely matches the CROMs input routine than does Iterations I. Here, the variables are specified exactly, and need not vary by some fixed increment. For example, yield can take on values of 1, 10, 50, 100 and 500 KT. When the program is selected to run, it will perform the selected calculations five times - once for each yield. To obtain the results of these calculations the calculator must be attached to the printer. If not, the program will run and simply display the results of the last calculation. All others will have been run but not recorded or stored.

Up to five different variables may be given multiple values. When the program is executed, all possible combinations of the values will be used as inputs for the calculations. The number of calculations performed rises quickly as more variables are given values. Assume that five different variables are each given four different values. The calculator will then attempt to perform a calculation for all the combinations, which equals 4^5 or 1024 calculations.

This large number requires a long calculator running time. If all these calculations are needed, it is recommended that the user time a few calculations to determine when the calculator will stop. It is prudent to select only those values necessary for the parameter study so that the calculator will run for a reasonable length of time.

The program itself is divided into two parts: card side 1a is used to set the variable inputs, and card side 1b is used to accept the additional inputs required to run the calculations. When side 1a is read into the machine, the user inputs the register number(s) of the variable(s) to be given multiple values, and the values chosen. Side 1b is then read into

the machine; at that point, the procedure for entering data and starting the calculations is exactly the same as for normal CROM operation.

B. Inputs

The inputs required for any series of calculations are those given in the main body of this document, which also describes the limits imposed by the CROM calculations.

For those inputs which will take different values in the course of these multiple calculations, the user will enter, in response to a "prompt" by the machine, the storage register number corresponding to that variable. The card face shows the required register number(s); it is shown at the key position at which that value is normally entered using the CROM's universal input routine.

Note that keys D and E sometimes accept two inputs. If two inputs (e.g., VN, k) are needed, the values will be stored at the respective register numbers. As an example, if VN and k were entered at key D, VN would be at R19, k at R13. However, if only one input is needed at key D or E, the register number corresponding to that input is the one underlined (for key D, R13, for key E, R14).

C. Limits

Limits are imposed by the CROM on any given call. When a limit is exceeded, the exceeded limit is printed with an error and execution for that particular example terminates. Control returns to the iterations program, which will resume the exercise with the next example.

D. General Instructions for Data Entry

1. Read side 1a of card
2. Press RST, then R/S, to begin data entry
3. In response to a prompt (?REG), enter register number for first variable to be assigned multiple values. Press R/S.
4. After prompt (?PTS), enter the number of values to be assigned that variable. Press R/S.
5. After prompt (?PT 1 or ?PT n), enter the value to be taken. Press R/S. Repeat for each value.

6. After those values are entered, machine will prompt again (?REG) for another variable. If another variable is to be given multiple values, repeat steps 3, 4, and 5 for that variable.
7. When all multiple-valued inputs have been entered, press CLR, read side 1b of card.
8. Turn to the section of this document that describes the calculation being performed, enter the indicated inputs and initiate the program by entering the appropriate a.b code number with key E'.

EXAMPLE #1:

Calculate the weapon radius for a 10P3 target using the iteration control program for the following combinations of inputs:

Yield (KT) = .4, 1, 4 HOB = 0, 750, 1000 (ft)

NOTES:

1. See card image at the beginning of this description for an association of registers to keys.
2. Side 1a. automatically repartitions the calculator to 239.89 for the variable input values. Side 1b. is recorded in this partition for program execution. If side 1b. is allowed to run to completion, the calculator is automatically repartitioned to 479.59 so that side 1a. can again be read. If side 1b. is stopped prematurely, an on/off sequence or manual repartition to 479.59 is necessary to read side 1a. again. However, any side, once read, may be exercised over and over without partitioning difficulties.

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
1	Turn off, then on			0.	
2	Read side 1a only			1.	
3	Begin program.		RST	1.	
	"1. LOOP" indicates that the calculator is receiving inputs for the first loop. Yield normally enters at key A, which according to the program card is Register 10. Only a register from 10 to 20 should be input for the prompt ?REG.		R/S	10.2	1. LOOP ?REG
4	Enter loop 1 register (yield). (See note 1) ?PTS asks for the number of loop 1 values. The 41 in the display indicates the maximum number allowed. Yield has three values in this case.	10	R/S	41	10. REG ?PTS
5	Enter total number of values for loop 1. $1 \leq PTS \leq 41$	3	R/S	1.	3. PTS 1. ?PT 1
6	Enter first yield value, PT 1	.4	R/S	2.	.4 PT 1 2. ?PT 2
7	Enter second yield value, PT 2	1	R/S	3.	1. PT 2 3. ?PT 3
8	Enter third yield value, PT 3	4	R/S		4. PT 3
9	Now the printer indicates that loop 2 is ready for values. HOB is in Register 11 from the card.			10.2	2. LOOP ?REG

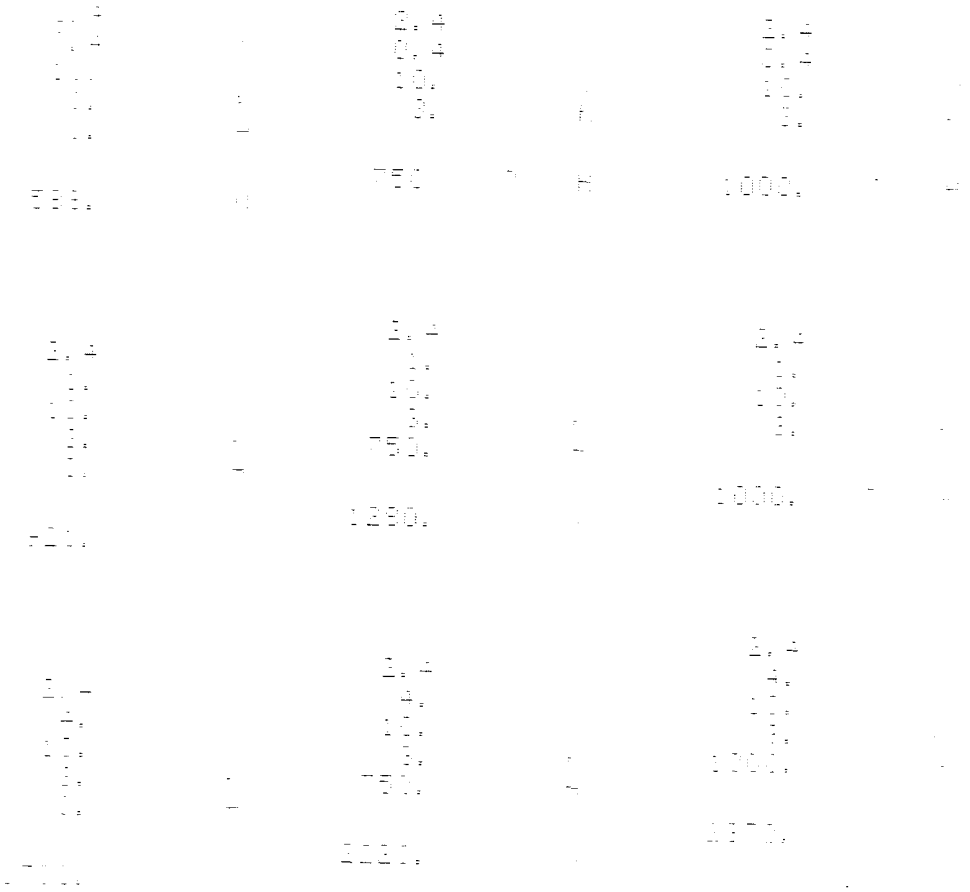
EXAMPLE #1 (continued)

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
10	Enter loop 2 register, (HOB) The 38 which appears in the display indicates the maximum number of values which may be entered for PTS.	11	R/S	38.	11. REG ?PTS
11	Enter total number of values for loop 2.	3	R/S	1.	3. PTS 1. ?PT 1
12	Enter first HOB value, PT 1	0	R/S	2.	0. PT 1 2. ?PT 2
13	Enter second HOB value, PT 2	750	R/S	3.	750. PT 2 3. PT 3
14	Enter third HOB value, PT 3	1000	R/S	10.2	1000. PT 3 3. LOOP ?REG
15	Press CLR. Read side 1b. (see note 2.) The calculator now acts as though in Pgm 01.		CLR	1.	
16	Enter VN	10	D	10.	
17	Enter k-factor	3	E	3.	
18	Initiate calculations	2.4	2nd E'		See Printer Output

PRINTER OUTPUT FOR EXAMPLE #1:

```
  1.      LOOP

          ?REG
 10.       REG

          ?PTS
  3.       PTS

  1.     ?PT  1
 0.4      PT  1

  2.     ?PT  2
  1.      PT  2

  3.     ?PT  3
  4.      PT  3

  2.      LOOP

          ?REG
 11.       REG

          ?PTS
  3.       PTS

  1.     ?PT  1
  0.      PT  1

  3.     ?PT  2
 -30.     PT  2

  4.     ?PT  3
 -40.     PT  3

  1.      LOOP

          ?REG
```

PRINTER OUTPUT FOR EXAMPLE #1 (continued):



PARTITION	FLAG	COMMENTS	FLAG	COMMENTS
AUTOMATIC	0,1,2,7,9	Used by CROM		

LIBRARY MODULE: CROM A-1

DATA REGISTERS FOR EXAMPLE 1

DATA	REG.	COMMENTS	STEP	CODE	LABELS KEY	COMMENTS
		Program n.m				
		Pointer registers; also used by CROM				Side a Parameter loop Data point loop
						Side b
						Unpacker Initiate calc.
		Universal I/O registers				5th parameter 4th parameter 3rd parameter 2nd parameter 1st parameter
						Universal I/O
		Used by CROM				
		Temporary storage				
		R34-R39: Pointers to registers for parameters to vary				

DATA	REG.	COMMENTS
		R39-R44: Starting location and number of values for each of five parameters
		R49-R59: Values that parameters take in increments

SIDE 1a

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS	STEP	CODE	KEY	COMMENTS
			Start				"LOOP"
			Pointer to starting location of first set of data				
			Number of free data points				
			Repartition				
			Pointer to register storing number of points and their pointer				"?REG"
			Pointer to pointers of registers to increment				
			Loop counter				
			Label x^2.				10.2 in display
			Begin loop				Read ith register
			Pointer to data points to be stored				Store pointer to ith register
			Data point counter				

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
095	00	0	
096	22	LBL	
097	14	D	"?PTS"
098	14	D	
099	11	A	
100	16	EXC	
101	11	A	
102	01	1	
103	16	EXC	
104	00	0	
105	22	LBL	
106	14	D	
107	00	0	
108	42	STO	Read number of data points that are associated with ith register
109	00	0	
110	42	STO	Counter to number of data points
111	00	0	
112	44	SUM	
113	00	0	
114	55	÷	
115	01	1	
116	00	0	
117	00	0	
118	55	÷	
119	44	SUM	
120	04	4	Pack information
121	42	STO	
122	04	4	
123	00	0	
124	44	SUM	
125	00	0	
126	43	RCL	Store pointer to starting location of registers for next set of data.
127	00	0	
128	00	0	
129	44	SUM	
130	04	4	
131	22	LBL	
132	24	√x	Label √x.
133	43	RCL	
134	00	0	
135	45	y^x	
136	43	RCL	
137	00	0	
138	00	0	
139	55	÷	
140	01	1	
141	44	INT	
142	00	STO	

STEP	CODE	KEY	COMMENTS
143	01	1	
144	00	0	
145	55	÷	
146	43	RCL	
147	00	0	
148	00	0	
149	01	1	
150	00	0	
151	00	0	
152	43	RCL	
153	00	0	
154	05	5	
155	00	0	
156	02	2	
157	00	0	
158	03	3	
159	00	0	
160	44	SUM	
161	00	0	
162	04	4	
163	00	0	
164	55	÷	Calculate alphanumerics for "PT L"
165	01	1	
166	04	4	
167	00	0	
168	55	÷	
169	01	1	
170	00	0	
171	00	0	
172	55	÷	
173	01	1	
174	00	0	
175	00	0	
176	55	÷	
177	01	1	
178	00	0	
179	00	0	
180	55	÷	
181	01	1	
182	00	0	
183	00	0	
184	55	÷	
185	01	1	
186	00	0	
187	00	0	
188	55	÷	
189	01	1	
190	00	0	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS	STEP	CODE	KEY	COMMENTS
			"END"				

SIDE 1b

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
000	[illegible]	LBL	Label INT.
001	[illegible]	INT	
002	[illegible]	INV	Unpack number of points
003	[illegible]	INT	in nth loop
004	[illegible]		
005	[illegible]		
006	[illegible]		
007	[illegible]		
008	[illegible]		
009	32	RTN	
010	[illegible]	LBL	
011	[illegible]		LABEL E'. start calc.
012	[illegible]		
013	[illegible]	STO	Pgm n.m.
014	[illegible]		
015	[illegible]		
016	[illegible]		
017	[illegible]		
018	[illegible]		
019	[illegible]		
020	[illegible]		
021	[illegible]		
022	[illegible]		
023	[illegible]		
024	[illegible]		
025	[illegible]		
026	[illegible]		
027	[illegible]		
028	[illegible]		
029	[illegible]		
030	[illegible]		Label LNX.
031	[illegible]		
032	[illegible]		Set up fifth looping
033	[illegible]		register
034	[illegible]		
035	[illegible]		
036	[illegible]		
037	[illegible]		
038	[illegible]		
039	[illegible]		
040	[illegible]		
041	[illegible]		
042	[illegible]		
043	[illegible]		Store data point of
044	[illegible]		fifth loop
045	[illegible]		
046	[illegible]		
047	[illegible]		
048	[illegible]		
049	[illegible]		
050	[illegible]		
051	[illegible]		
052	[illegible]		
053	[illegible]		
054	[illegible]		
055	[illegible]		
056	[illegible]		
057	[illegible]		
058	[illegible]		
059	[illegible]		
060	[illegible]		
061	[illegible]		
062	[illegible]		
063	[illegible]		
064	[illegible]		
065	[illegible]		
066	[illegible]		
067	[illegible]		
068	[illegible]		
069	[illegible]		
070	[illegible]		
071	[illegible]		
072	[illegible]		
073	[illegible]		
074	[illegible]		
075	[illegible]		
076	[illegible]		
077	[illegible]		
078	[illegible]		
079	[illegible]		
080	[illegible]		
081	[illegible]		
082	[illegible]		
083	[illegible]		
084	[illegible]		
085	[illegible]		
086	[illegible]		
087	[illegible]		
088	[illegible]		
089	[illegible]		
090	[illegible]		
091	[illegible]		
092	[illegible]		
093	[illegible]		
094	[illegible]		
095	[illegible]		

STEP	CODE	KEY	COMMENTS
043	[illegible]	LBL	Label CE.
044	[illegible]	CE	
050	[illegible]	[illegible]	Set up fourth looping
051	[illegible]	[illegible]	register
052	[illegible]	[illegible]	
053	[illegible]	[illegible]	
054	[illegible]	[illegible]	
055	[illegible]	[illegible]	
056	[illegible]	[illegible]	
057	[illegible]	[illegible]	
058	[illegible]	[illegible]	
059	[illegible]	[illegible]	Store data point of
060	[illegible]	[illegible]	fourth loop
061	[illegible]	[illegible]	
062	[illegible]	[illegible]	
063	[illegible]	[illegible]	
064	[illegible]	[illegible]	
065	[illegible]	[illegible]	
066	[illegible]	[illegible]	
067	[illegible]	[illegible]	
068	[illegible]	[illegible]	
069	[illegible]	[illegible]	
070	[illegible]	[illegible]	Label CLR.
071	[illegible]	[illegible]	
072	[illegible]	[illegible]	Set up third looping
073	[illegible]	[illegible]	register
074	[illegible]	[illegible]	
075	[illegible]	[illegible]	
076	[illegible]	[illegible]	
077	[illegible]	[illegible]	
078	[illegible]	[illegible]	
079	[illegible]	[illegible]	
080	[illegible]	[illegible]	Store data point of
081	[illegible]	[illegible]	third loop
082	[illegible]	[illegible]	
083	[illegible]	[illegible]	
084	[illegible]	[illegible]	
085	[illegible]	[illegible]	
086	[illegible]	[illegible]	
087	[illegible]	[illegible]	
088	[illegible]	[illegible]	
089	[illegible]	[illegible]	Label LOG.
090	[illegible]	[illegible]	
091	[illegible]	[illegible]	Set up second looping
092	[illegible]	[illegible]	register
093	[illegible]	[illegible]	
094	[illegible]	[illegible]	
095	[illegible]	[illegible]	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS	STEP	CODE	KEY	COMMENTS
094	42	STO		144			
095	00	00		145			
				146			
				147			
				148			
				149			
			Store data point for second loop	150			Innermost loop
				151			Second loop
				152			Third loop
			Label CP.	153			
			Set up first looping register	154			Fourth loop
				155			Fifth loop
				156			
				157			
			Set up data point for first loop.	158			
				159			
			Preserve R12	160			
				161			
				162			
				163			
				164			
				165			
				166			
				167			
				168			
				169			
				170			
			Call Pgm. n.m	171			"END"
				172			
				173			
			Restore R12	174			
140	42	STO		175			Label A.
141	12	12		176		H	
142	22	INV		177	42	STO	Store 10

PROGRAM MEMORY (LIST)

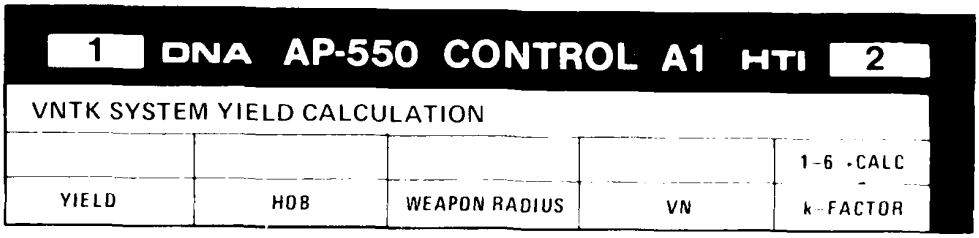
STEP	CODE	KEY	COMMENTS	STEP	CODE	KEY	COMMENTS
							Store 18
			Label B.				
			Store 11				
			Label C.				
			Store 12				
			Label D.				
			R19 = R13 R13 = x				
			Label E.				
			R20 = R14 R14 = x				
			Label A'.				
			Store 15				
			Label B'.				
			Store 16				
			Label C'.				
			Store 17				
			Label D'.				

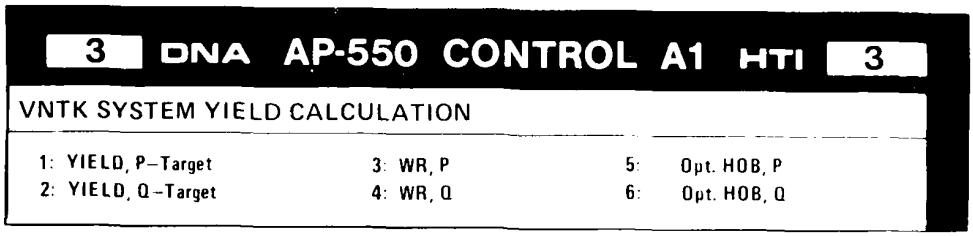
APPENDIX C: INVERSIONS

VNTK Weapon Radius Inversion for Yield

Personnel Weapon Radius Inversion for Yield

Cratering Second DOB Calculation





DESCRIPTION:

A. Objective

This code inverts the AP-550 CROM's VNTK program (program 02) for yield (Y), given a height of burst, a weapon radius (WR), a vulnerability number (VN), and a k-factor. Inputs are entered with keys A-E, and a calculation is initiated by entering one of six options (entered as an integer between 1 and 6) with key E'. The six options are:

1. Invert P-target weapon radius calculation for yield.
2. Invert Q-target weapon radius calculation for yield.
3. Calculate weapon radius, P-target.
4. Calculate weapon radius, Q-target.
5. Calculate optimum HOB and maximum WR, P-target.
6. Calculate optimum HOB and maximum WR, Q-target.

The weapon radius varies relatively slowly with heights of burst below the optimum height of burst. For this reason, a direct inversion of the calculation for the height of burst is not useful and has not been included. Instead, the CROM calculation of the optimum height of burst may be used to indicate the upper limit of desirable heights of burst.

B. Inputs - Outputs

Inputs: Yield (KT) (except options 1 and 2)
HOB (ft) (except options 5 and 6)

WR (ft) (except options 3, 4, 5, and 6)
VN
k-factor

Outputs: Yield (options 1 and 2)
HOB (options 5 and 6)
WR (options 3, 4, 5, and 6)

C. Limits (appropriate units are kilotons and feet)

Yield: $0.1 \text{ KT} \leq Y \leq 30 \text{ MT}$ (options 3,4,5,6)

HOB: $0 \leq \text{HOB} \leq \text{HOB}_{max}$ (options 3,4)

where:

$\text{HOB}_{max} = 2308\ Y^{1/3} \exp(-\text{AJVN}/15)$, P-target

HOB_{max} = the minimum of: $900\ Y^{1/3}$, $2308\ Y^{1/3} \exp(-\text{AJVN}/15)$ } Q-target

$0 \leq \text{HOB} \leq$ optimum HOB (options 1,2)

WR: $(0.1)^{1/3} W_1 \leq \text{WR} \leq (30{,}000)^{1/3} W_2$ (options 1,2)

where:

W_1 = scaled weapon radius at HOB = 0

W_2 = scaled weapon radius at optimum HOB

VN: $0 \leq \text{AJVN} \leq 56$, P-target

$0 \leq \text{AJVN} \leq 34$, Q-target

k-factor: $0 \leq k \leq 9$

D. Data Storage Locations, Printer Alphanumerics

Variables	Registers	Alphanumerics
Yield (KT)	R10	Y
HOB (ft)	R11	H
Weapon radius (ft)	R12	W
VN	R13	V
k-factor	R14	K

EXAMPLE #1:

Find the yield necessary to produce a weapon radius of 15,000 ft, for a target with a VNTK of 10P3. Assume a surface burst.

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
1	Turn off, then on			0	
2	Read sides 1, 2, 3 of cards			1,2,3	
3	Enter height of burst (ft)	0	B	0.	
4	Enter weapon radius (ft)	15000	C	15000.	
5	Enter VN	10	D	10.	
6	Enter k-factor	3	E	3.	
7	Initiate inversion for P-target	1	2nd E'		1. 10. V 3. K 0. H 15000. W
	Read yield			1170.	1170. Y
8	Verify that this yield will produce a 15,000 ft weapon radius	3	2nd E'		3. 1170. Y 10. V 0. K 15000. W

EQUATIONS

Definitions

Y = yield (KT)

H = height of burst (ft)

WR = weapon radius (ft)

VN = VN number

k = k factor

Yield inversion (calculations 1 and 2)

Using c, x_0, a and p as defined below (equations 23 through 31) calculate first guess for $Y = Y_1$ as follows:

$$AJVN_0 = VN \tag{1}$$

$$c_0 = c \text{ calculated using } AJVN_0 \text{ (equations 23, 28)} \tag{2}$$

$$Y_1 = (WR/c_0)^3 \tag{3}$$

Adjust VN using equations 18-22 and Y_1 as yield to get $AJVN_1$ (4)

$$c_1 = c \text{ calculated with } AJVN_1 \text{ (equations 23, 28)} \tag{5}$$

$$W_1 = c_1 Y_1^{1/3} \tag{6}$$

$$Y_2 = (WR/c_1)^3 \tag{7}$$

Adjust VN using equations 18-22 and Y_2 as yield to get $AJVN_2$ (8)

$$c_2 = c \text{ calculated with } AJVN_2 \text{ (equations 23, 28)} \tag{9}$$

$$W_2 = c_2 Y_2^{1/3} \tag{10}$$

$$\text{Improved first guess } \tilde{Y}_1 = \exp\left[\frac{\ln\left(\frac{W_2}{WR}\right) \cdot \ln Y_1 - \ln\left(\frac{W_1}{WR}\right) \cdot \ln Y_2}{\ln\left(\frac{W_2}{W_1}\right)}\right] \tag{11}$$

Adjust VN using equations 18-22 and $\hat{Y}_1$ as yield; and calculate (12)

$$W_1 = \left[1 + a\left(\frac{H}{x_0 Y_1^{1/3}}\right)^p\right] Y_1^{1/3} \quad (13)$$

Then $\hat{Y}_2 = \left(\frac{WR}{W_1}\right)^3 \hat{Y}_1$ = improved second guess (14)

Adjust VN using equations 18-22 and $\hat{Y}_2$ as yield; and calculate (15)

$$W_2 = \left[1 + a\left(\frac{H}{x_0 Y_2^{1/3}}\right)^p\right] Y_2^{1/3} \quad (16)$$

$$\text{Finally, } Y = \exp\left[\frac{\ln\left(\frac{W_2}{WR}\right)\ln Y_1 - \ln\left(\frac{W_1}{WR}\right)\ln Y_2}{\ln\left(\frac{W_2}{W_1}\right)}\right] \quad (17)$$

NOTE: If K-factor = 0, then calculations begin with equation (12), with AJVN VN.

Adjustment of VN:

For P-target, AJVN = VN + 11 nx (18)

where

$$x = \frac{1}{2}\frac{k}{10}\left(\frac{20}{Y}\right)^{1/3} + \left\{\left[\frac{1}{2}\frac{k}{10}\left(\frac{20}{Y}\right)^{1/3}\right]^2 + 1 - \frac{k}{10}\right\}^{1/2} \quad (19)$$

For Q-target, AJVN = VN + 8.2 nx, (20)

where

$$x = x_0 - \left[3x_0^2 - \frac{k}{10}\left(\frac{20}{Y}\right)^{1/3}\right]\frac{1}{6x_0} +$$

$$\left\{\left(\left[3x_0^2 - \frac{k}{10}\left(\frac{20}{Y}\right)^{1/3}\right]\frac{1}{x_0}\right)^2 - \frac{1}{3x_0}\left(x_0^3 - \frac{k}{10}\left(\frac{20}{Y}\right)^{1/3} x_0 - \frac{k}{10} - 1\right)\right\}^{1/2} \quad (21)$$

$$x_0 = \frac{k}{10}\left(\frac{20}{Y}\right)^{1/6} + 1 - \frac{k}{10} \tag{22}$$

For P-target

$$\text{[illegible]} = \exp(7.63 - AJVN/6) + \exp(7.37 - AJVN/16) \tag{23}$$

$$x_0 = \exp(6 + \text{[illegible]}2 - VN/13.7) \tag{24}$$

$$a = \text{[illegible]} \frac{(26 - AJVN)^4}{1890 + 31(26 - AJVN)^3} \text{ for AJVN} \leq 26 \tag{25}$$

$$a = \frac{(AJVN - 26)}{160} \text{ for AJVN} > 26 \tag{26}$$

$$p = .6 + \exp[-.393AJVN + 9.5\ln(.393AJVN) - 3.3^2] \tag{27}$$

For Q-target

$$\text{[illegible]} = [\exp(133 - 1.82AJVN) + \exp(128 - 1.4AJVN)]^{1/16} \tag{28}$$

$$x_0 = [\exp(-.24^2 AJVN)]^{.5}\left\{960 - 410\left[\frac{\exp(.27AJVN^{1.2} - 6.5)}{1 + \exp(.27AJVN^{1.2} - 6.5)}\right]\right\} \tag{29}$$

$$a = \frac{1}{\text{[illegible]}}[\exp(158 - 1.4AJVN) + \exp(177 - 2.7AJVN)]^{1.20} - 1 \tag{30}$$

$$p = [1 + (AJVN/33)^8]^{-1} \tag{31}$$

Calculations 3, 4, 5, and 6 use the same equations as are in the CROM (program 2).

PARTITION	FLAG	COMMENTS	FLAG	COMMENTS
559.49	0,1,2,7,9	Used by CROM	4	Set if 0 target
AUTOMATIC	3	Flags first acceleration in yield inversion		
LIBRARY MODULE				
CROM A-1				

DATA REGISTERS FOR EXAMPLE _____

DATA	REG.	COMMENTS
	0	Calc. index (used by CROM)
	1	Used by CROM
	2	Used by CROM
	3	Used by CROM
	4	-2
	5	Adjusted to VN (by CROM)
	6	Y_1
	7	W_1/WR
	8	Y_2
	9	W_2/WR
	10	Y (as finally calculated)
	11	HOB
	12	WP
	13	VN
	14	k factor
	15	WR (temporary storage)
	16	Not used
	17	Not used
	18	Not used
	19	Not used
	20	Not used
	21	Not used
	22	Not used
	23	Not used
	24	Not used
	25	Not used
	26	Not used
	27	Not used
	28	Not used
	29	Not used
	30	Not used
	31	Not used
	32	Not used
	33	Not used
	34	Not used
	35	Not used
	36	Not used
	37	Not used
	38	Not used
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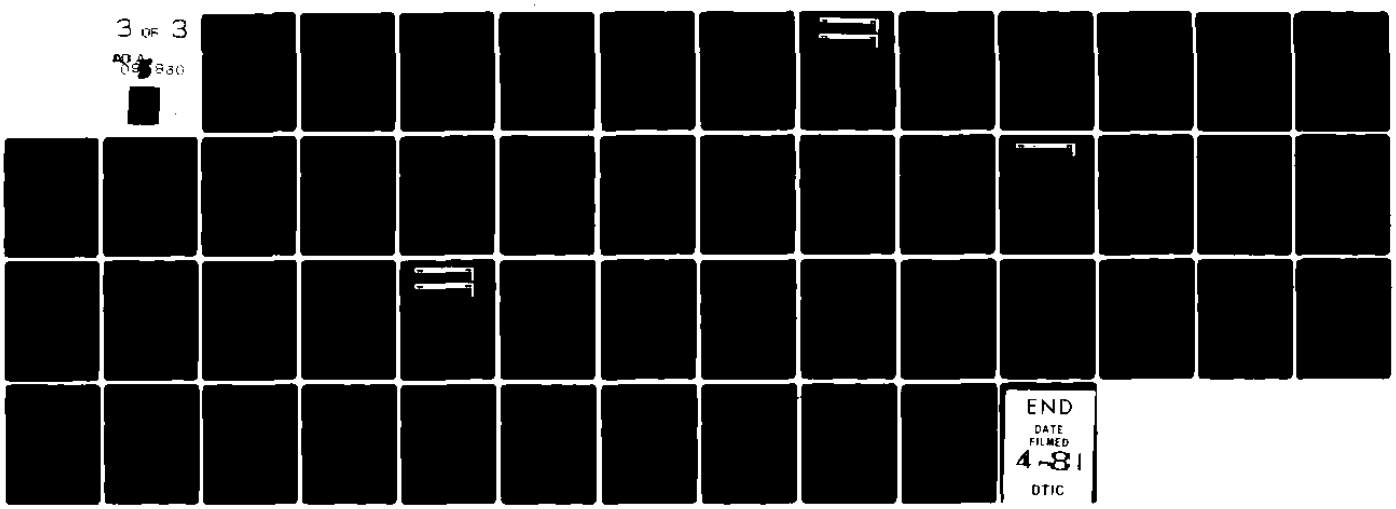
STEP	CODE	LABELS KEY	COMMENTS
			Calc. -2
			Aitken's accel.
			Calc. guess for
			Adjust
			Store yield
			Store HOB
			Store WP
			Store
			Store k factor
			Calc.

AD-A095 830 HORIZONS TECHNOLOGY INC SAN DIEGO CA F/G 18/3
NUCLEAR WEAPONS TARGETING, AP-550, CROM A1, REFERENCE MANUAL.(U)
JUN 79 DNA001-78-C-0247
UNCLASSIFIED HTI-R-79-125 DNA-5277H NL



PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
000	98	ADV	End of routines
001	98	ADV	
002	98	ADV	
003	92	RTN	
004	76	LBL	Label B'.
005	17	B'	Calculate α-2
006	87	IFF	Flag 4 set = Q target
007	04	04	
008	03	03	
009	73	73	
010	36	PGM	
011	02	02	
012	71	SBR	
013	04	04	
014	66	66	P-target α
015	61	GTO	
016	03	03	
017	76	76	
018	76	LBL	Label C'.
019	18	C'	
020	43	RCL	Aitken's acceleration
021	09	09	W_2/WR or $\tilde{W}_2/WR$
022	23	LNX	
023	65	×	
024	43	RCL	Y_1
025	06	06	
026	23	LNX	
027	75	-	
028	43	RCL	W_1/WR or $\tilde{W}_1/WR$
029	07	07	
030	23	LNX	
031	65	×	
032	43	RCL	Y_2
033	08	08	
034	23	LNX	
035	95	=	
036	55	÷	
037	53	(	
038	43	RCL	
039	09	09	W_2/W_1 or $\tilde{W}_2/\tilde{W}_1$
040	55	÷	
041	43	RCL	
042	07	07	
043	54	)	
044	23	LNX	
045	95	=	
046	22	INV	
047	23	LNX	
048	42	STO	
049	10	10	
050	92	RTN	
051	76	LBL	Label A'.
052	16	A'	Subroutine to calculate guess for Y and associated Ws
053	19	D'	
054	22	INV	Adjust VN
055	87	IFF	Flag 3 set for first accel., reset for 2nd
056	03	03	
057	04	04	Full WR calculation
058	36	36	Calculate α
059	17	B'	
060	61	GTO	
061	05	05	
062	32	32	
063	76	LBL	Label D'.
064	19	D'	Adjust VN with present yield
065	43	RCL	
066	14	14	k
067	55	÷	
068	01	1	
069	00	0	
070	65	×	
071	42	STO	
072	01	01	
073	42	STO	
074	04	04	
075	69	OP	
076	34	34	
077	53	(	
078	43	RCL	
079	10	10	
080	22	INV	Calculation of $Y^{-1/3}$
081	45	Y×	
082	03	3	
083	94	+/-	
084	65	×	
085	42	STO	
086	22	22	
087	01	1	
088	32	INV	
089	23	LNX	
090	55	÷	
091	87	IFF	
092	04	04	
093	03	03	
094	82	82	
095	02	2	P target

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
096	95	=	
097	85	+	
098	53	(	
099	33	X^2	
100	75	-	
101	43	RCL	
102	04	04	
103	54	)	
104	34	$\sqrt{x}$	
105	95	=	x
106	23	LNX	
107	65	×	
108	01	1	
109	01	1	
110	61	GTO	
111	04	04	
112	25	25	
113	76	LBL	Label A.
114	11	A	
115	42	STO	Input Y
116	10	10	
117	92	RTN	
118	76	LBL	Label B.
119	12	B	
120	42	STO	Input H
121	11	11	
122	92	RTN	
123	76	LBL	Label C.
124	13	C	
125	42	STO	Input WR
126	12	12	
127	92	RTN	
128	76	LBL	Label D.
129	14	D	
130	42	STO	Input VN
131	13	13	
132	92	RTN	
133	76	LBL	Label E.
134	15	E	
135	42	STO	Input k
136	14	14	
137	92	RTN	
138	76	LBL	Label E'.
139	10	E'	Enter calc. number to
140	88	ADV	begin.
141	59	INT	
142	32	X:T	
143	35	CLR	

STEP	CODE	KEY	COMMENTS
144	01	1	
145	85	+	Check and print calcula-
146	06	6	tion number
147	42	STO	Initialize for ST*00's
148	00	00	in yield inversion
149	65	×	
150	00	0	
151	36	PGM	
152	09	09	
153	11	A	
154	55	÷	
155	32	X:T	
156	02	2	
157	85	+	
158	59	INT	
159	95	=	
160	67	EQ	
161	01	01	Set flag 4 if even
162	64	64	(Q-target calc.)
163	22	INV	
164	86	STF	
165	04	04	
166	05	5	
167	69	DP	Repartition
168	17	17	
169	43	RCL	*Remove input WR to safe*
170	12	12	place
171	42	STO	
172	15	15	
173	02	2	
174	77	GE	
175	02	02	Yield inversion
176	13	13	
177	93	.	
178	04	4	
179	49	PRD	R_{00} = 2.4 to get CROM
180	00	00	to tranfer to Pgm. 3,
181	01	1	print WR.
182	00	0	R_{02} = 10 WS expected by
183	42	STO	CROM.
184	02	02	
185	04	4	
186	77	GE	
187	02	02	
188	01	01	WR calculation
189	87	IFF	
190	04	04	WR optimum H calcula=
191	01	01	tion

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
192	97	97	
193	36	PGM	P target
194	02	02	
195	13	C	
196	81	RST	
197	36	PGM	WR, optimum H calculation for Q target
198	02	02	
199	14	D	
200	81	RST	
201	87	IFF	----------
202	04	04	
203	02	02	WR calculation
204	09	09	
205	36	PGM	
206	02	02	P target
207	11	A	
208	81	RST	
209	36	PGM	
210	02	02	Q target
211	12	B	
212	81	RST	
213	86	STF	----------
214	03	03	Yield inversion
215	43	RCL	
216	13	13	
217	42	STO	$AJVN_0$ = VN
218	21	21	
219	17	B'	$\alpha_0 - 2$
220	71	SBR	
221	05	05	
222	44	44	Calculate $Y_1 \rightarrow R_{10}$
223	43	RCL	
224	14	14	Skip first acceleration if k = 0
225	29	CP	
226	67	EQ	
227	02	02	
228	34	34	
229	16	A'	W_1, Y_2
230	16	A'	W_2, extraneous "Y_3"
231	18	C'	Acceleration
232	42	STO	
233	06	06	$\tilde{Y}_1$
234	22	INV	
235	86	STF	
236	03	03	
237	07	7	Reinitialize R_{00}
238	42	STO	for indirect STORES.
239	00	00	

STEP	CODE	KEY	COMMENTS
240	16	A'	
241	16	A'	
242	18	C'	→Final Y
243	19	D'	Adjust VN with final Y
244	17	B'	Calculate α-?
245	87	IFF	
246	04	04	
247	03	03	
248	58	58	→Q-target
249	42	STO	
250	12	12	
251	43	RCL	
252	21	21	AJVN
253	94	+/-	
254	36	PGM	
255	02	02	
256	71	SBR	
257	00	00	
258	91	91	
259	42	STO	x_0
260	01	01	
261	36	PGM	
262	02	02	
263	71	SBR	
264	04	04	
265	86	86	
266	42	STO	
267	00	00	$\hat{W}_{max}$
268	05	5	
269	06	6	
270	75	-	
271	43	RCL	$\begin{Bmatrix}11\\8.2\end{Bmatrix}$ℓnx
272	22	22	
273	95	=	
274	42	STO	Upper limit for VN
275	23	23	
276	43	RCL	
277	15	15	
278	42	STO	Put WR back before
279	12	12	getting stuck in
280	01	1	limit checks!
281	03	3	
282	42	STO	
283	02	02	
284	04	4	
285	02	2	"V"
286	32	X:T	
287	43	RCL	

limit checks

PROGRAM MEMORY (LIST)

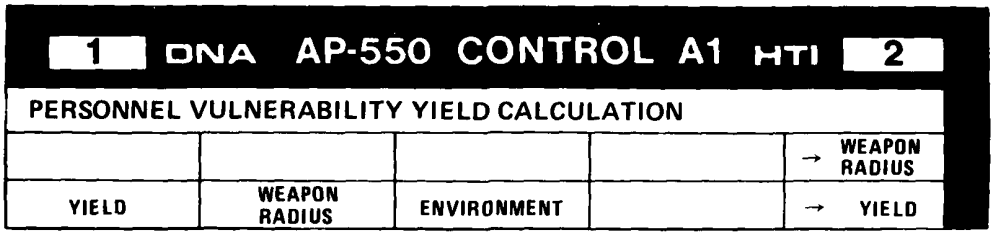
STEP	CODE	KEY	COMMENTS
288	22	22	
289	75	-	
290	50	I×I	
291	95	=	
292	55	÷	
293	02	2	
294	94	+/-	
295	44	SUM	$R_{00} = \alpha(a+1)-2$
296	00	00	
297	85	+	$\max\left\{0, -\left(\frac{11}{8.2}\right)\ell nx\right\}$
298	43	RCL	
299	23	23	
300	36	PGM	
301	09	09	
302	13	C	
303	02	2	"k"
304	06	6	
305	32	X:T	
306	00	0	
307	85	+	
308	09	9	
309	36	PGM	
310	09	09	
311	13	C	
312	01	1	
313	01	1	
314	42	STO	
315	02	02	
316	79	x̄	
317	32	X:T	
318	00	0	
319	85	+	
320	02	2	"H"
321	03	3	
322	32	X:T	
323	36	PGM	
324	09	09	
325	13	C	
326	04	4	"W"
327	03	3	
328	32	X:T	
329	93	.	
330	04	4	
331	06	6	$(.1)^{1/3}$
332	65	×	
333	43	RCL	
334	00	00	
335	85	+	
336	03	3	
337	01	1	$(30,000)^{1/3}$
338	93	.	
339	01	1	
340	65	×	
341	43	RCL	
342	04	04	
343	36	PGM	
344	09	09	
345	13	C	
346	98	ADV	
347	04	4	
348	05	5	
349	32	X:T	Print yield, rounded to 3 digits
350	43	RCL	
351	10	10	
352	36	PGM	
353	09	09	
354	12	B	
355	42	STO	
356	10	10	
357	81	RST	
358	36	PGM	
359	02	02	Calculation for yield inversion, limit checks, Q-target
360	19	D'	
361	42	STO	
362	01	01	$\hat{H}_{opt}$
363	36	PGM	
364	02	02	
365	17	B'	$\alpha(a+1)$
366	42	STO	
367	00	00	
368	03	3	AJVN max
369	04	4	
370	61	GTO	
371	02	02	
372	70	70	
373	36	PGM	Part of Label B'
374	02	02	
375	16	A'	Q-target α compensates for CROM's adjustment of WR by $2\gamma^{1/3}$
376	75	-	
377	02	2	
378	95	=	
379	42	STO	
380	04	04	
381	92	RTN	
382	49	PRD	part of Label D'
383	01	01	Q-target

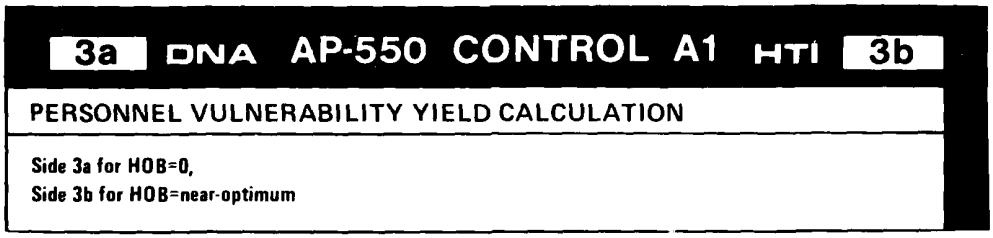
PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
384	34	$\sqrt{x}$	VN adjustment
385	54	)	
386	75	-	
387	43	RCL	
388	04	04	
389	95	=	
390	42	STO	
391	03	03	
392	55	÷	
393	02	2	
394	75	-	
395	79	$\bar{x}$	
396	55	÷	
397	06	6	
398	75	-	
399	53	(	
400	33	x^2	
401	75	-	
402	53	(	
403	43	RCL	
404	03	03	
405	33	x^2	
406	75	-	
407	43	RCL	
408	01	01	
409	85	+	
410	32	X:T	
411	54	)	
412	55	÷	
413	03	3	
414	54	)	
415	34	$\sqrt{x}$	
416	75	-	
417	43	RCL	
418	03	03	
419	95	=	x
420	23	LNX	
421	65	×	
422	08	8	
423	93	.	
424	02	2	
425	85	+	
426	48	EXC	
427	22	22	$R_{22} \leftarrow \begin{Bmatrix} 11 \\ 8.2 \end{Bmatrix} \ell nx$
428	42	STO	
429	03	03	
430	43	RCL	$R_{03} \leftarrow Y^{-1/3}$
431	13	13	
432	95	=	
433	42	STO	
434	21	21	AJVN
435	92	RTN	
436	87	IFF	Part of Label A'
437	04	04	
438	05	05	
439	28	28	(Q-target WR calc.)
440	17	B'	
441	02	2	Calculation of P-target
442	44	SUM	WR, adapted from CROM
443	04	04	
444	43	RCL	
445	11	11	
446	29	CP	Skip
447	67	EQ	if
448	05	05	H=0
449	20	20	
450	43	RCL	
451	21	21	
452	65	×	
453	93	.	
454	03	3	
455	09	9	
456	03	3	
457	75	-	
458	23	LNX	
459	65	×	
460	09	9	
461	93	.	
462	05	5	
463	85	+	
464	03	3	
465	93	.	
466	03	3	
467	33	x^2	
468	95	=	
469	94	+/-	
470	22	INV	
471	23	LNX	
472	85	+	
473	93	.	
474	06	6	
475	95	=	
476	42	STO	P
477	05	05	
478	43	RCL	
479	21	21	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
480	94	+/-	
481	36	PGM	
482	02	02	
483	71	SBR	
484	00	00	
485	91	91	
486	42	STO	
487	01	01	$\hat{H}_{opt}$
488	43	RCL	
489	11	11	
490	55	÷	
491	79	$\bar{x}$	
492	95	=	
493	45	Y^x	
494	43	RCL	
495	05	05	$\left(\frac{H}{H_{opt}}\right)^P$
496	95	=	
497	48	EXC	
498	04	04	
499	42	STO	
500	12	12	α
501	36	PGM	
502	02	02	
503	71	SBR	$\alpha(a+1)$
504	04	04	
505	86	86	
506	55	÷	
507	43	RCL	
508	12	12	
509	75	-	
510	01	1	
511	95	=	a
512	49	PRD	
513	04	04	
514	69	OP	
515	24	24	
516	43	RCL	
517	12	12	
518	49	PRD	
519	04	04	
520	36	PGM	
521	02	02	
522	71	SBR	Finish off WR calc.
523	04	04	
524	61	61	
525	61	GTO	
526	05	05	
527	32	32	
528	36	PGM	Q-target WR calc.
529	02	02	
530	71	SBR	
531	89	π	
532	79	$\bar{x}$	$Y^{-1/3}$ in R_{03}, $\hat{W}$ in R_{04}
533	43	RCL	
534	15	15	WR (given)
535	55	÷	
536	32	X:T	W_i
537	95	=	
538	72	ST*	R_{07} or R_{09}
539	00	00	
540	69	OP	
541	20	20	
542	43	RCL	
543	04	04	
544	55	÷	Entry point for first guess Y_1
545	43	RCL	
546	15	15	WR
547	65	×	
548	33	X^2	
549	95	=	$Y_{i+1} = \left(\frac{WR}{W_i}\right)^3$
550	35	1/X	
551	72	ST*	
552	00	00	R_{06} or R_{08}
553	69	OP	
554	20	20	
555	42	STO	New Y
556	10	10	
557	92	RTN	





SOURCE OF DATA:

Defense Intelligency Agency, Physical Vulnerability Handbook-Nuclear Weapons (U), AP-550-1-2-60-INT, June 1, 1969, Ch. 4.

DESCRIPTION:

A. Objective

This code finds the yield necessary to produce a specified personnel weapon radius for the twenty environments listed in section 4 for the surface and near-optimum HOB cases. The accuracy of this inversion of the CROMs program 04 will generally be within ±5%, although there may be a few areas with errors slightly larger.

The program uses two cards. The two sides of card one are read into banks 1 and 2 respectively. With the other card, the first side (marked 3a) is read into bank 3 for calculation of the surface burst case, and the second side (marked 3b) is read into bank 3 for the near-optimum HOB case.

For convenience, one can also, with this card, exercise the CROM Personnel Vulnerability calculation in the forward direction (i.e., finding WR, given the yield, etc.), without having to call Pgm 01. That calculation is begun through key 2nd E'; done in this way, the environment number is retained for successive calculations.

B. Inputs - Outputs

Inputs: Yield (KT) (for calculation of weapon radius)
HOB (ft)
Environment index
Weapon radius (ft) (for calculation of yield)

Outputs: Yield (KT)
HOB (optimum) (ft)
Weapon radius (ft)

C. Limits

Yield: $0.1 \leq Y \leq 30{,}000$ KT

HOB: $0 \leq HOB \leq 1000\ Y^{1/3}$ ft

Environment: Env. = 1,2,3,...20 (see section 4)

Weapon Radius: (limit is environment-dependent; maximum weapon radius corresponds to a yield of 30,000 KT, and minimum weapon radius corresponds to a yield of 0.1 KT.)

D. Data Storage

Variables	Registers	Alphanumerics
Yield	R10	Y
HOB	R11	H
Environment	R20	E
Weapon radius	R12	W

EXAMPLE #1:

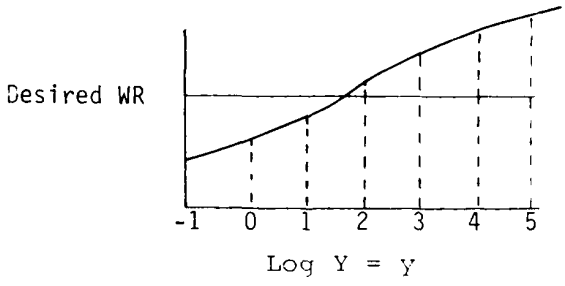
Calculate the yield that produces a weapon radius of 20,000 ft. for the near-optimum height of burst case, for the first environment category.

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
1	Turn off, then on			0	
2	Read both sides of first card, and second side of second card (3b) (first side is for surface burst case)		CLR	1,2,3	
3	Enter environment category	1	C	1.	
4	Enter weapon radius	20000	B	20000.	
5	Initiate calculation		E	 547.	20000. W 1. E 6540. H 547. Y

EQUATIONS

The inversions for yield are done by fitting a cubic interpolating polynomial through four values of the weapon radius curve around the point to be inverted, and inverting the polynomial for the desired yield. The values for the interpolating polynomial are obtained from a lookup table, as described below.

Each of the data registers 30-47 contains (in packed form) weapon radii at every decade of yield between 1 and 10^5, for environment categories 1-18, respectively. Data on the first side of the second card are for surface bursts, and data on the reverse side are for optimum heights of burst. The weapon radius for Y = .1 KT is obtained from the lookup table in Program 4 (and is adjusted to y_0' (adjusted weapon radius) in the optimum HOB case), thus providing information for WR for values of Log Y = -1, 0, 1, 2, 3, 4 and 5. Four points that "box" the desired weapon radius are chosen, so that two are greater than the desired WR, and two are less that the desired WR.



These four points define a unique cubic polynomial, which is set up as described below. Once these four points have been obtained, an approximate solution to the cubic equation is effected by first setting up a quadratic equation that interpolates the first three points on the graph, and inverting it for a "first guess" at Y, and then expanding the cubic polynomial into a second-order Taylor series about the "first series", and solving the resulting quadratic equation. This approximate inversion to the cubic polynomial is sufficiently accurate so that there is no significant deviation from the true solution to the cubic polynomial. The polynomial itself approximates the data to $\leq$ 2%, except in the transition

region around Y = 10 KT, when it gets as high as 4-7%. This gives an error in yield of ~ 5% normally, and ~ 20% in the transition region, in some cases.

The equations for this procedure are as follows. (The cubic polynomial is in log-log space).

Calling the four points along the abscissa that box the desired weapon radius (in log-log space) y_{-1}, y_0, y_1, y_2, and the corresponding ordinate points W_{-1}, W_0, W_1, W_2, then the quadratic formula that interpolates the first three points,

$$f_q(y-y_0) = a_q\,(y-y_0)^2 + b_q\,(y-y_0) + c_q \tag{1}$$

has coefficients

$$a_q = \frac{1}{2}(W_{-1} + W_1) - W_0 \tag{2}$$

$$b_q = \frac{1}{2}(W_1 - W_{-1}) \tag{3}$$

$$c_q = W_0 \tag{4}$$

and the cubic interpolating polynomial,

$$f_c(y - y_0) = a_c(y - y_0)^3 + b_c(y - y_0)^2 + c_c(y - y_0) + d_c \tag{5}$$

has coefficients

$$a_c = \frac{1}{6}(W_2 - 3W_1 + 3W_0 - W_{-1}) \tag{6}$$

$$b_c = \frac{1}{2}(W_{-1} + W_1) - W_0 = a_q \tag{7}$$

$$c_c = \frac{1}{6}(-2W_{-1} - 3W_0 + 6W_1 - W_2) = \frac{1}{2}(W_1 - W_{-1}) - a_c = b_q - a_c \tag{8}$$

$$d_c = W_0 = c_q \tag{9}$$

It is convenient to express these coefficients in a slightly different form:

let $\gamma = 2a_q = 2b_c$; (10)

$\beta = b_q$ (11)

$\alpha = W_0 = c_q = d_c$ (12)

$\delta = 3a_c = (\gamma + \beta) + \frac{1}{2}(W_0 - W_2)$ (13)

Calling y_q the solution to the quadratic formula, then

$$(y_q - y_o) = \frac{-\delta}{\gamma} + \text{sgn}(\gamma)\sqrt{\left(\frac{-\beta}{\gamma}\right)^2 - \frac{2(\alpha - W)}{\gamma}} \quad (14)$$

where $W = \ln WR$ (15)

and the cubic polynomial Taylor series expansion has the form

$$f(y - y_q) = f(y_q - y_0) + f'(y_q - y_0)(y - y_q) + \frac{1}{2}f''(y_q - y_0)(y - y_0)^2 \quad (16)$$

Where f' and f'' are the first and second derivatives of f, respectively.

$$\text{Let } r = \frac{f'(y_q)}{f''(y_q)} = \frac{y_q(\delta y_q + \gamma) + \beta - \delta/3}{(2\delta y_q + \gamma)} \quad (17)$$

Then using the approximation of (16),

$$(y - y_q) = -\gamma + \text{sgn}(2\delta y_q + \gamma)\sqrt{r^2 - \frac{2(f(y_q) - W)}{(2\delta y_q + \gamma)}} \quad (18)$$

which gives the final result,

$$\text{Yield} = 10^y \quad (19)$$

If $W > W_f$ (= ℓn WR at yield = 10^4 KT), then the yield is approximated as

$$\exp(W - W_f) = \left(\frac{Y}{10^4}\right)^{1/3} \tag{20}$$

or

$$Y = 10^4 \exp\left[-3(W_f - W)\right], \tag{21}$$

setting as an upper limit on WR

$$\exp(W - W_f) = 3^{1/3} \rightarrow WR_{max} = \exp\left(W_f + \frac{1}{3}\ell n 3\right) \tag{22}$$

The more accurate approximation calculates a weapon radius given this value of Y, and calculates a new Y (Yield) as

$$\left(\frac{Y_{new}}{Y}\right)^{1/3} = \left(\frac{WR_{new}}{WR}\right), \tag{23}$$

or

$$(Y_{new}) = Y\left(\frac{WR_{new}}{WR}\right)^3 \tag{24}$$

The last two categories can be inverted analytically for yield:

$$WR = \left[a + \alpha(Y - b)^P\right]^{-1} \quad \text{(see Program 4 equations)} \tag{25}$$

or

$$Y = \left[\frac{WR^{-1} - a}{\alpha}\right]^{-1/P} + b \tag{26}$$

The coefficients a, α, p and b are packed in registers 48 and 49, as:

	Class 19		Class 20	
	HOB = 0	HOB = optimum	HOB = 0	HOB = optimum
$\frac{1}{8} \times 10^4 a^{-1}$	110	679	1.0	502
$10^5 \alpha$	73	61	57	46
p	.445	.445	.462	.462
$10^5 b$	150	3939	125	2367

PARTITION	FLAG	COMMENTS	FLAG	COMMENTS
559.49	1	Suppresses CROM printing		
AUTOMATIC	2	For short or long calculation		
LIBRARY MODULE				
CROM A-1				

DATA REGISTERS FOR EXAMPLE 1

DATA	REG.	COMMENTS
101.	00	Subroutine addresses
965.1679343	01	
21.	02	= 10
0.122244873	03	
2134.733554	04	
.8288712994	05	
20000.	06	
20000.	07	
0.	08	
1638.648041	09	
547.	10	Yield
6540.	11	= 0
20000.	12	Weapon radius
12.	13	Address for environ-
6.2	14	ment-dependent coding
0.	15	
0.	16	
0.	17	
.3999999975	18	
6544.268239	19	
1.	20	Environment type
8.508009781	21	
9.904604435	22	
15.97562075	23	
2.951443219	24	
.2083570601	25	
.9999999993	26	
.0000362436	27	
5.491845105	28	
1562.250761	29	
8.6879193 11	30	
8.08291 11	31	
8.1849064 11	32	
8.08289 11	33	
7.7838452 11	34	
7.7808585 11	35	
5.5574533 11	36	
7.0785132 11	37	
4.9554335 11	38	
6.1604535 11	39	

LABELS

STEP	CODE	KEY	COMMENTS
005	18	C'	Retrieve data
019	18	A'	Retrieve R02 digits
025	17	B'	e-x
032	19	D'	→f(x),f'(x), f''(x)
057	14	D	quadratic form.
085	11	A	Y→
090	12	B	WR→
095	13	C	E→
100	10	E'	→WR
203	35	=	print output
435	15	E	→Y

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
000	43	ADV	End of calculation
001	43	ADV	
002	43	ADV	
003	91	R/S	
004	76	LBL	Label C'. Retrieve data for environment E
005	19	C'	
006	02	2	
007	09	9	
008	85	+	
009	43	RCL	E
010	20	20	
011	95	=	
012	42	STO	
013	00	00	
014	73	RC*	
015	00	00	
016	42	STO	Data table for relevant environment
017	13	13	
018	76	LBL	Label A'. Retrieve R02 digits from register 13. (data unpacking)
019	16	A'	
020	36	PGM	
021	04	04	
022	16	A'	
023	92	RTN	
024	76	LBL	*Label B'.*
025	17	B'	
026	54	)	
027	84	+/-	Calculate e^{-x}
028	22	INV	
029	23	LNX	
030	92	RTN	
031	76	LBL	Label D'. Used in calculating f'(x) and f(x) (where f(x) is cubic polynomial)
032	19	D'	
033	22	INV	
034	49	PRD	
035	24	24	
036	43	RCL	
037	24	24	
038	84	+/-	
039	75	-	
040	43	RCL	
041	25	25	
042	85	+	
043	43	RCL	
044	01	01	
045	55	÷	
046	53	(	
047	24	CE	
048	65	×	Entry point for calculating f''(x)
049	43	RCL	
050	14	14	
051	85	+	
052	43	RCL	
053	13	13	
054	95	=	
055	92	RTN	
056	76	LBL	Label D. Quadratic formula, to invert for x
057	14	D	
058	85	+	
059	53	(	
060	33	x^2	
061	75	-	
062	02	2	$2 \times \ldots$
063	65	×	
064	53	(	
065	43	RCL	(f(x) ...
066	12	12	
067	75	-	
068	43	RCL	
069	12	12	
070	23	LNX	- y) ...
071	54	)	
072	55	÷	
073	43	RCL	: f''(x)
074	23	23	
075	54	)	
076	34	$\sqrt{x}$	
077	65	×	
078	43	RCL	
079	23	23	
080	69	DP	
081	10	10	$\text{sgn}(f''(x))=\text{sgn}\left[\frac{f'(x)}{f''(x)}\right]$
082	95	=	
083	92	RTN	
084	76	LBL	Label A. Enter Yield
085	11	A	
086	42	STO	
087	10	10	
088	92	RTN	
089	76	LBL	Label B. Enter weapon radius
090	12	B	
091	42	STO	
092	12	12	
093	92	RTN	
094	76	LBL	Label C. Enter environment type
095	13	C	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
096	42	STO	
097	20	20	
098	43	RTN	
099	76	LBL	Label E'.
100	15	E'	
101	05	5	
102	34	FX	
103	11	11	
104	36	PAU	
105	01	01	Calculate WR
106	06	06	Advance paper
107	44	SUM	
108	00	0	Subroutine sets up a CROM call to calculate WR
109	42	STO	
110	12	12	
111	40	+	
112	36	PAU	
113	05	05	
114	43	RCL	
115	00	00	
116	43	RCL	
117	20	20	
118	00	E	
119	01	1	Preserve old WR
120	42	STO	
121	08	08	
122	43	RCL	
123	04	04	
124	36	PAU	
125	04	04	
126	36	PAU	
127	03	03	
128	42	STO	
129	14	14	
130	43	RTN	
131	01	1	Case for environment category 15
132	55	=	
133	01	1	
134	44	SUM	Start of inversion for WR
135	10	10	
136	43	LN	
137	01	1	W→t
138	42	STO	
139	09	09	
140	33	LN/X	
141	77	GE	
142	55	=	
143	43	RCL	y_0'=lower limit for WR
144	10	10	
145	42	STO	
146	00	00	
147	76	LBL	
148	11	A	
149	43	RCL	
150	00	00	
151	43	RCL	
152	01	01	
153	55	÷	
154	43	RCL	
155	02	02	
156	65	×	
157	01	1	
158	00	0	
159	00	0	
160	00	0	
161	00	0	
162	55	÷	
163	03	3	
164	50	y^x	
165	43	RCL	
166	00	00	
167	75	-	
168	01	1	
169	00	0	
170	00	0	
171	00	0	
172	00	0	
173	55	÷	
174	03	3	
175	65	×	
176	43	RCL	
177	00	00	
178	40	+	
179	43	RCL	
180	01	01	
181	42	STO	
182	00	00	
183	43	RCL	
184	00	00	
185	43	RCL	
186	01	01	
187	42	STO	
188	01	01	
189	43	RCL	
190	00	00	
191	55	÷	

Set up W_1

Shift W_1, W_2, W_3 until $W_3 \cdot W$

Case for $W \cdot W_f$ ($W_f = W/_{Y=10^4}$)

Calculate upper limit on WR:

$WR_{max} = \exp(W_f + \frac{1}{3}/n3)$

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
192	03	3	
193	17	B'	
194	65	×	
195	01	1	
196	52	EE	
197	04	4	$Y+10^4\exp[-3(W_f-W)]$
198	87	IFF	
199	02	02	
200	03	03	Calculate WR(Y) and adjust Y
201	47	47	
202	76	LBL	Label =.
203	95	=	
204	95	=	
205	42	STO	
206	10	10	Calculated Yield.
207	22	INV	
208	45	Y×	
209	03	3	
210	55	÷	
211	49	PRD	
212	11	11	R11 = HOB = $\hat{H}\ Y^{1/3}$
213	22	INV	
214	86	STF	
215	01	01	
216	06	6	
217	69	DP	
218	17	17	
219	43	RCL	
220	09	09	
221	85	+	
222	43	RCL	
223	12	12	
224	32	X↑T	Print WR
225	65	×	
226	04	4	
227	03	3	
228	36	PGM	
229	09	09	
230	11	A	
231	01	1	
232	07	7	
233	32	X↑T	
234	02	2	
235	00	0	Print environment
236	42	STO	
237	02	02	
238	36	PGM	
239	09	09	
240	16	A'	
241	02	2	
242	03	3	
243	32	X↑T	
244	43	RCL	
245	11	11	
246	36	PGM	
247	09	09	Print HOB
248	12	B	
249	42	STO	
250	11	11	
251	33	ADV	
252	04	4	
253	05	5	
254	32	X↑T	
255	43	RCL	
256	10	10	
257	36	PGM	Print Yield
258	09	09	
259	12	B	
260	42	STO	
261	10	10	
262	61	GTO	
263	42	STO	Set up interpolating polynomial:
264	23	23	
265	16	A'	
266	95	=	R23 = W_3
267	42	STO	
268	24	24	R24 = W_4
269	43	RCL	
270	21	21	
271	45	Y×	
272	48	EXC	
273	23	23	
274	44	SUM	
275	23	23	
276	95	=	2β
277	44	SUM	
278	24	24	
279	55	÷	
280	43	RCL	
281	22	22	
282	94	+/-	
283	44	SUM	
284	23	23	
285	44	SUM	
286	23	23	γ in R23
287	44	SUM	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
288	24	24	
289	02	2	
290	55	÷	
291	42	STO	
292	25	25	β in R25
293	43	RCL	
294	23	23	
295	22	INV	
296	44	SUM	
297	24	24	
298	22	INV	
299	44	SUM	2δ in R24
300	24	24	
301	14	D	
302	42	STO	
303	01	01	Solve for $(y_q - Y_0)$
304	71	SBR	
305	00	00	
306	48	48	Calculate $f''(y_q - Y_0)$
307	32	X↕T	
308	03	3	
309	35	1/X	
310	65	×	
311	02	2	
312	19	D'	Calculate $f'(y_q - Y_0)$
313	94	+/-	
314	48	EXC	
315	22	22	$-f'(y_q - y_0)\downarrow\uparrow\alpha$
316	85	+	
317	02	2	
318	22	INV	
319	49	PRD	
320	23	23	
321	43	RCL	
322	01	01	
323	65	×	
324	53	(	
325	03	3	
326	19	D'	
327	48	EXC	
328	22	22	$f(y_q-y_0)\downarrow\uparrow-f'(y_q-y_0)$
329	55	÷	
330	43	RCL	
331	12	12	
332	32	X↕T	
333	42	STO	$f''(y_q-y_0)$
334	23	23	
335	14	D	
336	85	+	
337	43	RCL	
338	01	01	
339	85	+	
340	04	4	$(y-y_q)+(y_q-y_0)+4$
341	75	-	
342	43	RCL	
343	00	00	
344	95	=	$\log Y=(y-y_q)+(y_q-y_0)+$
345	22	INV	4-R00
346	28	LOG	
347	95	=	
348	42	STO	Y(obtained from cubic
349	10	10	spirals)
350	32	X↕T	
351	42	STO	
352	07	07	Store limit on WR
353	71	SBR	
354	01	01	Calculate WR at newly
355	08	08	found yield.
356	35	1/X	
357	65	×	
358	43	RCL	
359	07	07	
360	32	X↕T	
361	43	RCL	
362	06	06	
363	42	STO	
364	12	12	
365	65	×	
366	33	X²	
367	95	=	Correction to yield
368	49	PRD	
369	10	10	
370	61	GTO	
371	02	02	
372	13	13	
373	25	CLR	Environment categories
374	01	1	19 and 20
375	06	6	
376	52	EE	
377	04	4	
378	55	-	
379	71	SBR	
380	05	05	
381	57	57	
382	32	X↕T	upper limit on WR
383	18	C'	$10^{-4}\hat{A}$

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
384	42	STO	
385	11	11	
386	01	1	
387	52	EE	
388	04	4	
389	43	PRD	$\hat{H}$ in R11
390	11	11	
391	55	÷	
392	01	1	
393	00	0	
394	42	STO	
395	09	09	
396	43	PRD	
397	09	09	Lower limit on WR
398	43	PRD	
399	02	02	(so as to retrieve 2
400	55	÷	digits at a time)
401	16	A'	
402	65	×	$\frac{1}{\alpha}$ ×...
403	53	(	
404	43	RCL	
405	12	12	
406	35	1/X	
407	75	-	
408	08	8	
409	55	÷	
410	01	1	
411	52	EE	
412	06	6	
413	55	÷	
414	01	1	
415	00	0	
416	43	PRD	
417	02	02	
418	55	÷	
419	16	A'	... $\frac{1}{WR}$ - a
420	95	=	
421	22	INV	
422	45	YX	
423	16	A'	
424	84	+/-	-P
425	85	+	
426	43	RCL	
427	13	13	
428	55	÷	
429	01	1	
430	52	EE	
431	05	5	b

STEP	CODE	KEY	COMMENTS
432	61	GTO	
433	95	=	
434	76	LBL	Label E.
435	15	E	
436	25	CLR	Initiate calculation
437	42	STO	
438	11	11	R11 = 0
439	36	STF	
440	02	02	
441	36	STF	
442	01	01	
443	22	INV	
444	58	FIX	
445	32	IN	
446	57	ENG	
447	05	5	
448	68	DSP	Repartitions
449	17	17	
450	43	RCL	
451	20	20	Environment to t
452	32	XIT	
453	01	1	
454	00	0	
455	42	STO	R02 = 10
456	02	02	
457	65	×	
458	01	1	Environment categor-
459	08	8	ies 19 and 20, go to
460	22	INV	373
461	77	GE	
462	03	03	
463	73	73	
464	01	1	
465	05	5	
466	67	EQ	
467	01	01	
468	33	33	Environment category
469	32	XIT	15, go to 133
470	95	=	
471	06	6	
472	02	2	
473	01	1	
474	95	=	
475	42	STO	
476	13	13	
477	36	PGM	Retrieve data for y_0
478	04	04	and H_{opt}
479	71	SBR	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
480	40	IND	
481	13	13	
482	55	÷	
483	01	1	Start of case for $\hat{H}_{opt}$. Listing for surface burst case is shown after listing for $\hat{H}_{opt}$ case
484	00	0	
485	00	0	
486	95	=	
487	59	INT	
488	42	STO	
489	13	13	Packed data
490	16	A'	
491	55	÷	
492	93	.	
493	01	1	
494	22	INV	
495	49	PRD	Change number of digits to be retrieved
496	02	02	
497	22	INV	
498	67	EQ	
499	05	05	
500	02	02	
501	55	÷	
502	93	.	
503	00	0	
504	00	0	
505	01	1	
506	95	=	
507	42	STO	
508	11	11	$\hat{H}$
509	16	A'	
510	16	A'	
511	85	+	
512	03	3	
513	95	=	
514	22	INV	
515	23	LOG	unpack Y_0
516	75	-	
517	01	1	
518	08	8	
519	00	0	
520	95	+	
521	24	CE	Start of calculation for y'_0
522	65	×	
523	53	(	
524	24	CE	
525	85	+	
526	32	X↔T	
527	05	5	

STEP	CODE	KEY	COMMENTS
528	00	0	
529	33	X²	
530	85	+	
531	93	.	
532	06	6	
533	85	+	
534	93	.	
535	08	8	
536	65	×	
537	43	RCL	
538	11	11	
539	33	X²	
540	55	÷	
541	32	X↔T	
542	33	X²	
543	85	+	
544	01	1	
545	02	2	
546	04	4	
547	55	÷	
548	43	RCL	
549	11	11	
550	55	÷	
551	34	√x	
552	17	B'	y'_0
553	61	GTO	
554	01	01	
555	34	34	
556	00	0	
557	01	1	Indicator to program that $\hat{H}_{opt}$ case is in memory
558	95	=	
559	32	RTN	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
479	71	SBR	Program for HOB=0
480	40	IND	
481	13	13	
482	55	÷	
483	01	1	
484	52	EE	
485	05	5	
486	95	=	
487	54	INT	
488	43	STO	Retrieve packed data
489	12	12	
490	01	1	
491	00	0	
492	44	PRD	
493	02	02	
494	16	A'	
495	85	+	
496	03	3	
497	95	=	
498	22	INV	
499	36	LOG	
500	75	-	
501	01	1	
502	08	8	
503	00	0	
504	95	=	Unpack $y_0 = y_0'$
505	31	GTO	
506	01	01	
507	35	35	
508	00	0	
509	00	0	
510	00	0	
511	00	0	
512	00	0	
513	00	0	
514	00	0	
515	00	0	
516	00	0	
517	00	0	
518	00	0	
519	00	0	
520	00	0	
521	00	0	
522	00	0	
523	00	0	
524	00	0	
525	00	0	
526	00	0	
527	00	0	
528	00	0	
529	00	0	
530	00	0	
531	00	0	
532	00	0	
533	00	0	
534	00	0	
535	00	0	
536	00	0	
537	00	0	
538	00	0	
539	00	0	
540	00	0	
541	00	0	
542	00	0	
543	00	0	
544	00	0	
545	00	0	
546	00	0	
547	00	0	
548	00	0	
549	00	0	
550	00	0	
551	00	0	
552	00	0	
553	00	0	
554	00	0	
555	00	0	
556	00	0	
557	02	2	Indicator to program that surface burst case is in memory.
558	95	=	
559	42	RTN	

1	DNA AP-550 CONTROL A1 HTI			1
CRATERING, 2nd DOB CALCULATION				
				7.n → CALC
YIELD	HOB	MEDIUM	CRATER RADIUS	→ 2nd DOB

SOURCE OF DATA:

Defense Intelligency Agency, Physical Vulnerability Handbook - Nuclear Weapons (U), AP-550-1-2-69-INT, June 1, 1969, Part II.

DESCRIPTION:

A. Objective

Program 7.1 of the AP-550 CROM calculates the upper of two depths of burst of yield Y, which will produce a crater of a specified radius, (R), in the designated earth medium, (M). This control program calculates the greater of the two depths, and, for convenience in comparison, will exercise program 07 if desired. Keeping with the convention established, a depth of burst is referred to as a negative HOB.

B. Inputs - Outputs

The user enters the weapon yield, (Y), crater radius, (R), and medium number, (M), corresponding to one of these media:

Dry rock (M=1)
Wet rock (M=2)
Dry soil (M=3)
Wet soil (M=4)

Inputs may be entered in any order.

The program includes limits for all entered values:

$0.1 \leq Y \leq 30{,}000$ KT

$1 \leq M \leq 4$

$0 \leq R \leq$ upper limit (U.L.)

$$\begin{cases} \text{U.L.} = 151(Y)^{0.3} & \text{for M=1} \\ \text{U.L.} = 172(Y)^{0.3} & \text{for M=2} \\ \text{U.L.} = 159(Y)^{0.3} & \text{for M=3} \\ \text{U.L.} = 210(Y)^{0.3} & \text{for M=4} \end{cases}$$

After the calculation is initiated, the program checks each value against its limits and prints the value. If a limit is violated, the calculator stops printing the inputs and

flashes the exceeded limit in the display. The input value is printed with a question mark and put in the t-register. To re-enter an acceptable value, press CLR and re-enter the new value into the appropriate key. Then press R/S to start the calculation over.

The calculation can be started by pressing key E or R/S after the appropriate data is entered.

C. Special Features

The five cratering calculation options given in Section 7 of this document can also be run by entering the appropriate calculation number in key 2nd E'. The program leaves the calculator in the radian angular mode.

D. Data Storage Locations and Printer Alphanumerics

The user may find the following information in the indicated registers.

Variable	Register	Alphanumerics
Yield	R10	Y
Medium	R12	M
Radius	R13	R
HOB	R11	H

EXAMPLE #1:

Find the greatest depth of burst (a negative HOB means a distance below the ground) for which a 10-KT weapon will produce a crater radius of 315 feet in wet soil.

Compare this to the DOB nearer the surface at which the same weapon will produce the same crater radius.

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
1	Turn off, then on			0	
2	Read one side of program card			1.	
3	Enter yield, Y (KT)	10	A	10.	
4	Enter crater radius, R (ft)	315	D	315.	
5	Enter medium number (1=dry rock, 2=wet rock, 3=dry soil, 4=wet soil)	4	C	4.	
6	Calculate the DOB (ft)		E		10. Y 4. M 315. R -447. H
7	Calculate the upper DOB (A)	7.1	2nd E'		7.1 10. Y 4. M 315. R -72.4 H

PRINTER OUTPUT:

```
   10.        Y
    4.        M
  315.        R

 -447.        H
```

```
    7.1
   10.        Y
    4.        M
  315.        R

 -72.4        H
```

EQUATIONS

Definitions

Y = Yield (kilotons)

HOB = Height of Burst (feet)

R = Crater Radius (feet)

$$\text{Define z:} \quad z = \arcsin\left[\frac{\ln \frac{R}{Y^{0.3}} + d}{c}\right] \tag{1}$$

$$\text{Then HOB} = -3.3(Y)^{0.3}\exp\left[\frac{a - (z)^{20/3}}{b}\right] \tag{2}$$

The coefficients are:

Coefficient	Dry Rock	Wet Rock	Dry Soil	Wet Soil
a	150.0	153.0	117.0	128.3
b	37.0	36.0	25.0	29.0
c	6.02	5.15	5.07	8.35
d	1.0	0.0	0.0	3.0

NOTE:

Equation (2) is an analytic inversion of the crater radius curvefit equation:

$$R = (Y)^{0.3}\exp\left\{c \sin\left|\left(a - b\ln\left(\frac{-HOB}{3.3Y^{0.3}}\right)\right)^{0.15}\right| - d\right\}$$

PARTITION	FLAG	COMMENTS	FLAG	COMMENTS
479.59	Not used			

AUTOMATIC

LIBRARY MODULE

CROM A-1

DATA REGISTERS FOR EXAMPLE 1

DATA	REG.	COMMENTS
7.1	00	n.n
47.64059995	01	Temp
3.	02	Temp
21.93244743	03	Temp
3.080019441	04	Temp
14.34667064	05	Temp
0.	06	
0.	07	
0.	08	
0.	09	
10.	10	Y
-72.4	11	H
4.	12	M
315.	13	R
0.	14	
0.	15	
0.	16	
0.	17	
0.	18	
0.	19	
0.	20	
156813056O.	21	Temp
0.	22	
0.	23	
-6.42029978[illegible]	24	Temp
14.34667064	25	Temp
3.080019441	26	Temp

LABELS

STEP	CODE	KEY	COMMENTS
017	16	A'	Unpacker rtne.
023	11	A	Store yield
029	13	C	Store medium
035	14	D	Store radius
038	34	[illegible]	Prepare for calc.
047	15	E	2nd HOB calc.
162	10	E'	CROM cratering
168	12	B	Store HOB

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
000	01	1	Upper Limit for radius M = 1
001	05	5	
002	01	1	
003	42	RTN	
004	01	1	Upper Limit for radius M = 2
005	07	7	
006	02	2	
007	42	RTN	
008	01	1	Upper Limit for radius M = 3
009	05	5	
010	09	9	
011	42	RTN	
012	02	2	Upper Limit for radius M = 4
013	01	1	
014	00	0	
015	42	RTN	
016	76	LBL	Label A'.
017	16	A'	
018	36	PGM	Call Pgm 7 Unpacker
019	07	07	
020	16	A'	
021	42	RTN	
022	76	LBL	Label A.
023	11	A	
024	42	STO	Store yield in R10
025	10	10	
026	81	GTO	Go to Label WRT
027	36	WRT	
028	76	LBL	Label C.
029	13	C	
030	42	STO	Store medium in R12
031	12	12	
032	81	GTO	Go to Label WRT
033	36	WRT	
034	76	LBL	Label D.
035	14	D	
036	42	STO	Store radius in R13
037	13	13	
038	76	LBL	Label WRT.
039	36	WRT	
040	32	X↕T	Remove scientific and fixed notation from display.
041	35	CLR	
042	32	INV	
043	58	FIX	
044	32	X↕T	
045	42	RTN	
046	76	LBL	Label E.
047	15	E	

STEP	CODE	KEY	COMMENTS
048	38	ADV	
049	32	INV	Reset flags 0 and 1
050	36	STF	
051	00	00	
052	32	INV	
053	36	STF	
054	01	01	
055	01	1	Store 10 in R02
056	00	0	
057	42	STO	
058	02	02	
059	36	PGM	Call yield limit checker and printer
060	07	07	
061	71	SBR	
062	45	Y^x	
063	69	DP	Add 1 to R02
064	22	22	
065	36	PGM	Call medium limit checker and printer
066	07	07	
067	71	SBR	
068	47	CMS	
069	04	4	
070	65	×	
071	43	RCL	4 × M - 4
072	12	12	
073	75	-	Store in R21
074	04	4	
075	95	=	Limit checks for radius
076	42	STO	
077	21	21	
078	00	0	Lower Limit = 0
079	85	+	
080	03	3	
081	05	5	Alphas for "R"
082	32	X↕T	
083	71	SBR	Call radius upper limit
084	40	IND	
085	21	21	
086	55	÷	Take U.L. × $(Y)^{0.3}$
087	36	PGM	
088	07	07	
089	15	E	
090	01	1	
091	36	PGM	Check limits and print radius
092	09	09	
093	13	C	
094	38	ADV	
095	01	1	Begin calculation

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
096	36	PGM	165
097	05	5	
098	35	+	+
099	02	2	
100	02	2	22
101	36	PGM	Call the routine to get
102	07	07	the coefficient string
103	17	B'	containing a, b, c and
104	03	3	d
105	42	STO	
106	02	02	R02 = 3
107	16	A'	
108	42	STO	Call unpacker to get a,
109	24	24	R24 = a
110	02	2	
111	16	A'	Call unpacker to get b,
112	42	STO	
113	25	25	R25 = b
114	01	1	
115	16	A'	Call unpacker to get c,
116	32	X:T	
117	36	PGM	put c in t register
118	07	07	
119	15	E	Calculation of eq. 1
120	43	RCL	
121	13	13	
122	95	=	
123	23	LNX	
124	85	+	
125	03	3	
126	16	A'	
127	95	=	
128	55	÷	
129	32	X:T	
130	95	=	
131	70	RAD	
132	22	INV	
133	38	SIN	z in display
134	22	INV	Calculation of eq. 2
135	45	Y^x	
136	93	.	
137	01	1	
138	05	5	
139	75	-	
140	43	RCL	
141	24	24	
142	95	=	
143	94	+/-	
144	55	÷	
145	43	RCL	
146	25	25	
147	95	=	
148	22	INV	
149	23	LNX	
150	36	PGM	Call routine to finish
151	07	07	eq. 2 and print small-
152	71	SBR	er HOB
153	06	06	
154	95	95	
155	98	ADV	
156	98	ADV	
157	98	ADV	
158	92	RTN	
159	61	GTO	Will do calculation
160	15	E	again when R/S pressed.
161	76	LBL	Label E'.
162	10	E'	
163	36	PGM	Call AP550 INPUT Pgm.
164	01	01	to begin calculation.
165	10	E'	
166	92	RTN	
167	76	LBL	Label B.
168	12	B	
169	42	STO	Store HOB in R11
170	11	11	
171	92	RTN	

APPENDIX D: PROBABILITY OF DAMAGE TO IRREGULARLY SHAPED TARGETS

1	DNA AP-550 CONTROL A1	HTI	2

PROBABILITY OF DAMAGE TO IRREGULARLY SHAPED TARGETS				
CEP	TARGET RADIUS	OFFSET	DAMAGE SIGMA	3.n → CALC
ANGLE	SIDE 1	WEAPON RADIUS	LENGTH OR SIDE 2	WIDTH OR SIDE 3

3	DNA AP-550 CONTROL A1	HTI	3

PROBABILITY OF DAMAGE TO IRREGULARLY SHAPED TARGETS				

SOURCE OF DATA:

Defense Intelligence Agency, Physical Vulnerability Handbook - Nuclear Weapons (U), AP-550-1-2-69-INT, June 1, 1969, Part IV.

DESCRIPTION:

A. Objective

The objective of this program set is to provide calculations of average probability of damage for rectangular, triangular and elliptical targets with uniform target element distributions. These programs use the Probability of Damage to Point Targets CROM program as a subroutine. The weighted point method is used and therefore target size limitations must be imposed to ensure accuracy. The limitations are:

Triangular target: longest side $\leq$ CEP
Rectangular target: diagonal $\leq$ CEP
Elliptical target: major axis $\leq 2 \times$ CEP

If target dimensions are greater than the limitations imposed above then the general case method for area targets should be used to compute the Pd. This method requires that the area target be divided into small cells of equal area whose greatest dimension is less than or equal to 1/4 of the CEP. Each cell is then considered a point target and the Pd to each cell is computed using the point target program with an offset equal to the distance from the DGZ to the center of each cell. The Pd to the whole area target is then obtained by averaging the Pd

to each cell. To implement the general case method for area targets, the user must use program 3.0 and then manually compute the average Pd.

B. Inputs - Outputs

The three calculations comprising this program set and their necessary inputs are as follows. Figure 3 gives a graphical representation of the inputs.

Program 3.3: Probability of damage - rectangular targets.
Inputs: Offset of the DGZ from the target center, (x) ft.
Angle between offset line and length, (A) deg.
Target length, (L) ft.
Target width, (WD) ft.

Program 3.4: Probability of damage - triangular targets.
Inputs: Offset of the DGZ from the "offset vertex", (x) ft.
Angle between offset line and side S1, (A) deg.
Lengths of the three sides, (S1, S2, S3) ft.
Note: Sides S1, S2 and S3 are defined by moving clockwise from the "offset vertex"; which is the triangle vertex to which the offset distance (x) is measured. (see figure 3)

Program 3.5: Probability of damage - elliptical targets.
Inputs: Offset of the DGZ from the target center, (x) ft.
Angle between offset line and major axis, (A) deg.
Length of major axis, (L) ft.
Length of minor axis, (WD) ft.

C. Limits

Rectangular targets:
Length (L): $WD \leq L \leq (CEP^2 - WD^2)^{1/2}$ ft.
Width (WD): $1 \leq WD \leq L$ ft.

Triangular targets:
Longest side (S): $1 \leq S \leq CEP$ ft.

Elliptical targets:
Major axis (L): $WD \leq L \leq 2 \times CEP$ ft.
Minor axis (WD): $1 \leq WD \leq L$ ft.

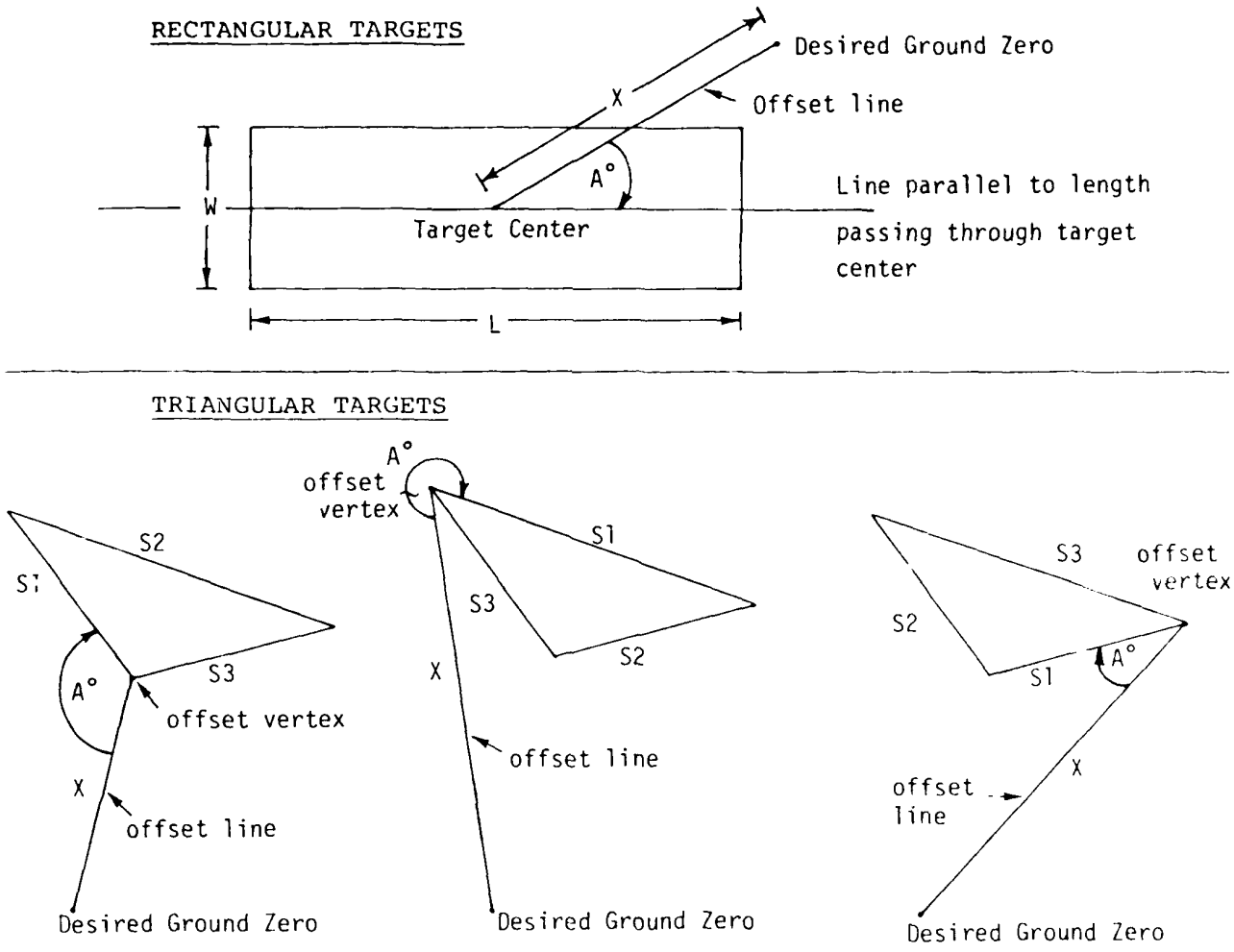


Figure 3. Definition of input dimensions for various area targets.

Input limits common to all target types:

Offset angle (A):	$A \geq 0$ deg.
Offset (x):	$x \geq 0$ ft.
CEP:	CEP ≥ 0 ft.
Damage sigma (S):	$0.1 \leq S \leq 0.5$
Weapon radius (W):	$W \geq 0$ ft.

D. Data Storage Locations and Printer Alphanumerics

The user can find the following information stored in the indicated registers.

Variables	Register	Alphanumerics
program no.	R00	--
angle	R10	A
triangle S1	R11	S1
weapon radius	R12	W
triangle S2	R13	S2
triangle S3	R14	S3
rect. length	R13	L
rect. width	R14	WD
major axis	R13	L
minor axis	R14	WD
CEP	R15	C
target radius	R16	TR
offset	R17	X
damage sigma	R18	S
Pd	R19	P

E. Special Features

The user may run the programs described in Section 3 of this documentation by entering the appropriate program designator (3.0, 3.1, or 3.2) with key 2nd E' of this control program. If this is done, a value for the target radius will be printed for all three programs even though the value is used in programs 3.1 and 3.2 only.

EXAMPLE #1: Probability of Damage to Area Targets

Given the following information:

Weapon Radius = 400 ft Offset = 200 ft.
CEP = 320 ft. Damage sigma = 0.4

calculate the average probability of damage for the following area targets.

(1) A 240-ft by 80-ft rectangle with a 53-degree angle between the offset and length lines.

(2) A 260-ft by 100-ft ellipse with the same angle between the offset and length (major axis) lines.

(3) A triangle with S1 = 100 ft, S2 = 100 ft, and S3 = 100 ft, and a 210-degree angle between offset line and S1 measured in the clockwise direction.

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
1	Turn off, then on			0	
2	Read both sides of card one, and one side of card two			1,2,3	
3	Enter weapon radius	400	C	400.	
4	Enter CEP	320	2nd A'	320.	
5	Enter offset	200	2nd C'	200.	
6	Enter damage sigma	.4	2nd D'	0.4	
	Target 1: Rectangle				
7	Enter target length	240	D	240.	
8	Enter target width	80	E	80.	
9	Enter angle between offset and length lines	53	A	53.	
10	Begin rectangular target calculation	3.3	2nd E'		3.3 400. W 320. C 0. T 200. X 0.4 S 53. A 240. L 80. WD
	(calculation takes 1.25 minutes)			0.432	0.432 P
	Target 2: Ellipse				
11	Enter target major axis	260	D	260.	
12	Enter target minor axis	100	E	100.	

EXAMPLE #1 (Cont.)

STEP	INSTRUCTIONS	INPUT	KEYS	DISPLAY	PRINT
13	Begin elliptical target calculation (calculation takes 1.8 minutes)	3.5	2nd E'	0.43	3.5 400. W 320. C 0. T 200. X 0.4 S 53. A 260. L 100. WD 0.43 P
	Target 3: Triangle				
14	Enter S1	100	B	100.	
15	Enter S2	100	D	100.	
16	Enter S3	100	E	100.	
17	Enter angle corresponding to the number of degrees in the clockwise direction between the offset line and S1.	210	A	210.	
18	Begin triangular target calculation (calculation takes 1.0 minutes)	3.4	2nd E'	0.416	3.4 400. W 320. C 0. T 200. X 0.4 S 210. A 100. S1 100. S2 100. S3 0.416 P

EQUATIONS

Definitions

WR = Weapon radius

X = Offset

σ = Damage sigma

CEP = Circular error probable

TR = Target radius

P = Probability of damage

Routines 3.0, 3.1 and 3.2

Initially the following adjusted values are calculated:

$$CEP_a = \sqrt{CEP^2 + kTR^2} \tag{1}$$

where k = 0 for point targets,

k = 0.231 for circular targets with normal distribution.

For circular targets with uniform distribution:

k = 0.4 when TR $\leq$ WR + CEP + x

k = 0.5 when TR > WR + CEP + x

$$W1 = WR \div CEP_a \tag{2}$$

For W1 $\leq$ 30, the following curvefit coefficients are calculated:

$$b = 26 \exp\left(-2.1\sigma - \frac{W1}{16}\right) \tag{3}$$

$$a = \exp\left|-\left(\frac{1339\exp(-42\sigma) - 2\sigma + 3.7}{W1}\right)^{\left[0.71\exp\left(\frac{\sigma}{0.3}\right)\right]}\right| - (\gamma + |\gamma|) \tag{4}$$

where $\gamma = 7000\sigma^{5.6}[\exp(-21\sigma)(W1-5.5)]$ (5)

$$R_0 = (3.6\sigma-2)W1 - (1.3+1.1\sigma)\ln[W1(0.24+\sigma)] \tag{6}$$

$$\varepsilon = W1 - 0.2 - (\beta + |\beta|) \tag{7}$$

$$\text{where } \beta = 0.61(W1 + 4\sigma - 3.2)\left(\sigma^{2.23} + \frac{10^{-5}}{\sigma^{2.23}}\right) \tag{8}$$

$$\varepsilon' = \ln\left[0.6\sigma + \frac{1}{\delta}\right] \tag{9}$$

$$\text{where } \delta = \frac{1}{1.2}\exp(10\sigma - 1.1W1) + \frac{1}{299}\exp\left[9.47\sigma - \frac{W1}{0.9}\exp(-2.69\sigma) - 2.7\ln\sigma\right] \tag{10}$$

$$T' = \tan[b(\varepsilon' - \varepsilon)] \tag{11}$$

$$L' = \ln[\ell + |\ell| + 10^{-5}] \tag{12}$$

$$\text{where } \ell = \frac{1}{2+\varepsilon-\varepsilon'} \tag{13}$$

With these coefficients, the code proceeds to calculate the probability:

$$X1 = X \div CEP_a \tag{14}$$

$$R' = 3.89\left\{\frac{(1-a)}{T'}\tan[b(X1 - \varepsilon)] + \frac{a}{L'}\ln\left[\frac{X1 - \varepsilon' + 2}{\varepsilon - \varepsilon' + 2}\right]\right\} \tag{15}$$

$$\text{for } X1 \geq 2, \quad R = -R' \tag{16}$$

$$\text{for } X1 < 2, \quad R = \cos(45X1)\left(R_0 + \frac{X1}{0.9} + R'\right) - R' \tag{17}$$

For $W1 > 30$, R is given by,

$$R = -0.07z^3 - 1.6z \tag{18}$$

$$\text{where } z = \ln\left[(1-\sigma^2)\frac{WR}{x}\right] \div \sqrt{-\ln(1-\sigma^2)} \tag{19}$$

And finally to go from the transformed R space to the probability P we have

$$P = \frac{1}{1 + \exp(R)} \tag{20}$$

Routine 3.3 Average Probability of Damage to Rectangular Targets

Definitions

D_i = distance from the desired ground zero to one of the four corners of the rectangle.

A = angle between the offset line and length

L = length of rectangle

WD = width of rectangle

P_r = average Pd to the rectangular target

For i = 1 to i = 4,

$$D_i = \left[(X\cos A - 0.5gL)^2 + (X\sin A - 0.5hWD)^2\right]^{1/2} \quad (21)$$

where $g = \text{sgn}[\cos(90i+45)]$ (22)

$h = \text{sgn}[\cos(90i-45)]$ (23)

(Sgn is the signum function.)

The following table shows i, g and h:

i	g	h
1	-1	1
2	-1	-1
3	1	-1
4	1	1

For each D_i, $P(D_i)$ the probability of damage to a point target for the desired ground zero a distance D_i from the target is calculated by setting $X = D_i$ in equations 14 through 20.

$$P_r = \frac{6P(X) + P(D_1) + P(D_2) + P(D_3) + P(D_4)}{10} \quad (24)$$

Routine 3.4 Average Probability of Damage to Triangular Targets

Definitions

D_{12} = distance from the desired ground zero to the vertex of sides S1 and S2

D_{23} = distance from the desired ground zero to the vertex of sides S2 and S3

S1, S2 and S3 = 3 sides of the triangle (see figure 3, p.D-5)

D_c = distance from the desired ground zero to the centroid of the triangle

P_T = Average Pd to the triangular target

$$D_{12} = [(S1)^2 + X^2 - 2(S1)X\cos A]^{\frac{1}{2}} \quad (25)$$

$$D_{23} = [(S3)^2 + X^2 - 2(S3)X\cos(A + \quad)]^{\frac{1}{2}} \quad (26)$$

where $\quad = \arccos\left[\frac{(S1)^2 + (S3)^2 - (S2)^2}{2(S1)(S3)}\right]$ (27)

$$D_c = [M^2 + X^2 - 2MX\cos(A+\quad)] \quad (28)$$

where $M = \frac{S1}{2}\frac{\sin(\quad)}{\sin(\quad+\quad)}$ (29)

$\quad = \arccos\left\{\frac{3(S1)^2 + (S3)^2 - (S2)^2}{(S1)[8(S1)^2 + 8(S3)^2 - 4(S2)^2]^{\frac{1}{2}}}\right\}$ (30)

$\quad = \arccos\left\{\frac{(S2)^2 - (S3)^2}{(S1)[2(S2)^2 + 2(S3)^2 - (S1)^2]^{\frac{1}{2}}}\right\}$ (31)

$$P_T = \frac{7P(D_c) + P(X) + P(D_{12}) + P(D_{23})}{10} \quad (32)$$

Routine 3.5 Average Probability of Damage to Elliptical Targets

Definitions

D_i = distance from the desired ground zero to the corners and midpoints of sides of an inscribed rectangle in the ellipse

A = angle between offset line and major axis

L = length of the major axis

WD = length of the minor axis

P_e = average Pd to an elliptical target

For i = 1 to i = 8

$$D_i = \left\{\left(X\cos A - \frac{f\sqrt{L^2 - WD^2}}{2}\right)^2 + \left(X\sin A - j\frac{WD^2}{2L}\right)^2\right\}^{\frac{1}{2}} \tag{33}$$

where $f = \text{sgn}[\cos(45i + 45)]$ (34)

$j = \text{sgn}[\cos(45i - 45)]$ (35)

The following table shows i, f and j

i	f	j
1	0	1
2	-1	1
3	-1	0
4	-1	-1
5	0	-1
6	1	-1
7	1	0
8	1	1

$$P_e = \frac{4[P(X)+P(D_1)+P(D_3)+P(D_5)+P(D_7)] + P(D_2)+P(D_4)+P(D_6)+P(D_8)}{24} \tag{36}$$

PARTITION	FLAG	COMMENTS	FLAG	COMMENTS
559.49	See Pgm. 3 A1 CROM flags			

AUTOMATIC

LIBRARY MODULE

CROM A-1

DATA REGISTERS FOR EXAMPLE _____

DATA	REG.	COMMENTS
3.4	00	Program no.
1.25	01	W1
15.	02	Print Routine Ind. Reg.
320.	03	CEP_a
284.2655304	04	Temp
0.4	05	Temp
0.	06	Temp
30.	07	Temp
10000.	08	Temp
-10000.	09	Temp
210.	10	A
100.	11	S1
400.	12	WR
100.	13	S2 or L
100.	14	S3 or WD
320.	15	CEP
0.	16	TR
200.	17	x
0.4	18	Damage Sigma
0.416	19	P
.5849765962	20	Temp
-1.05	21	-c
-1.141337315	22	c'
10.38094411	23	b
.0000645066	24	a
-.3117302207	25	R_0
-.4192967045	26	T'
-.7398517144	27	L'
4.164079106	28	Temp
0.	29	Registers 29 through 49
0.	30	unused
0.	31	
0.	32	
0.	33	
0.	34	
0.	35	
0.	36	
0.	37	
0.	38	
0.	39	

LABELS			
STEP	CODE	KEY	COMMENTS
001	11	A	Enter angle
005	36	CLR	Clear format
016	34	TRI	Triangle calc.
028	69	DSP	Limit checks
043	36	PGM	Calc. 3.0, 3.1, 3.2
052	11	COS	Cosine law
060	11	A	Distance calc.
111	11	C	Calc. $P(D_i)$
130	34	RAT	Limit checks
144	11	B	Rectangle calc.
158	11	RAD	Rectangle calc.
174	55	=	Print P
183	53	EE	Ellipse calc.
201	11	E	Ellipse calc.
220	11	S	Enter S1
227	11	W	Enter WR
235	11	Z	Enter SZ or L
248	11	D	Enter S3 or WD
260	11	R	Enter CEP
272	11	T	Enter TR
284	11	S	Enter Sigma
296	11	X	Enter x
310	11	F	Flag 7 check
319	36	SPC	Advance paper
326	36	PRT	Program stops here
338	11	E'	Begin calc.
411	11	P	Print angle

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
000	76	LBL	Label A.
001	11	A	
002	42	STO	Store angle in R10
003	10	10	
004	76	LBL	Label WRT.
005	96	WRT	
006	22	INV	Remove FIX and Scien-
007	58	FIX	tific display formats
008	22	INV	
009	57	ENG	
010	92	RTN	
011	43	RCL	Option to run same
012	00	00	calculation with R/S.
013	61	GTO	Put 3.n in display
014	10	E'	Go to Label E'
015	76	LBL	Label $\sqrt{x}$.
016	34	$\sqrt{x}$	
017	43	RCL	Calculation routine for
018	11	11	triangular targets
019	33	x^2	
020	85	+	$(S1)^2 + (S3)^2 - (S2)^2$
021	43	RCL	
022	09	09	
023	75	-	
024	43	RCL	
025	08	08	
026	92	RTN	
027	76	LBL	Label OP.
028	69	OP	Printout and limit
029	69	OP	check routine for
030	27	27	triangular targets
031	43	RCL	routine
032	07	07	Recall alphanumerics
033	32	X↑T	put in t register
034	01	1	Lower Limit = 1
035	85	+	
036	43	RCL	Upper Limit = CEP
037	15	15	
038	36	PGM	Call Pgm. 9 to check
039	09	09	limits and print
040	13	C	value
041	92	RTN	
042	76	LBL	Label PGM.
043	36	PGM	
044	36	PGM	Call CROM Pgm. 1 to do
045	01	01	calculations 3.0, 3.1,
046	71	SBR	and 3.2
047	00	00	
048	90	90	See Eqs. 1 through 20
049	61	GTO	Go to Label RTN
050	92	RTN	
051	76	LBL	Label COS.
052	39	COS	Routine used in the
053	65	×	triangular targets
054	53	(	calculation to perform
055	32	X↑T	cosine law.
056	85	+	
057	43	RCL	See eqs. 25, 26 and 27
058	10	10	
059	54	)	
060	39	COS	
061	65	×	
062	02	2	
063	65	×	
064	43	RCL	
065	17	17	
066	94	+/-	
067	85	+	
068	43	RCL	
069	17	17	
070	33	x^2	
071	85	+	
072	32	X↑T	
073	33	x^2	
074	95	=	
075	34	$\sqrt{x}$	
076	61	GTO	Go to Label GTO
077	61	GTO	
078	76	LBL	Label P/R.
079	37	P/R	Routine used in the
080	04	4	rectangular and
081	05	5	elliptical targets
082	65	×	calculations to calcu-
083	43	RCL	late D_i
084	06	06	
085	85	+	
086	04	4	See eqs. 21 and 33
087	05	5	
088	75	-	
089	42	STO	Calculation of g and h
090	09	09	(see eqs. 22 and 23)
091	09	9	or f and j (see eqs.
092	00	0	34 and 35)
093	95	=	
094	39	COS	
095	69	OP	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
096	10	10	
097	55	÷	
098	02	2	
099	65	×	
100	43	RCL	
101	08	08	
102	94	+/-	
103	85	+	
104	43	RCL	
105	17	17	
106	32	X↕T	
107	43	RCL	
108	10	10	
109	37	P/R	
110	95	=	
111	32	X↕T	
112	75	-	
113	43	RCL	
114	07	07	
115	55	÷	
116	02	2	
117	65	×	
118	43	RCL	
119	09	09	
120	39	COS	
121	69	OP	
122	10	10	
123	95	=	
124	22	INV	
125	37	P/R	
126	32	X↕T	
127	76	LBL	Label GTO.
128	61	GTO	
129	36	PGM	Call Pgm. 3 to calculate $P(D_i)$
130	03	03	
131	71	SBR	
132	00	00	See eqs. 24, 32 and 36
133	88	88	
134	44	SUM	Store sum of $P(D_i)$ in R28
135	28	28	
136	92	RTN	
137	76	LBL	Label PRT.
138	99	PRT	
139	43	RCL	Limit check and print-out routine for rectangular and elliptical targets
140	15	15	
141	33	X²	
142	95	=	
143	34	ΓX	
144	82	HIR	Upper limit
145	02	02	
146	02	2	
147	44	SUM	
148	02	02	
149	02	2	"L" alphanumerics
150	07	7	
151	32	X↕T	
152	43	RCL	Lower limit = WD
153	14	14	
154	36	PGM	Call Pgm. 9 to check
155	09	09	limits and print out L
156	13	C	
157	42	STO	Store L in R07
158	07	07	
159	04	4	
160	03	3	"WD" alphanumerics
161	01	1	
162	06	6	
163	32	X↕T	
164	01	1	
165	36	PGM	Call Pgm. 9 to check
166	09	09	limits and print out WD
167	13	C	
168	42	STO	Store WD in R08
169	08	08	
170	92	RTN	
171	76	LBL	Label RST.
172	81	RST	
173	43	RCL	Start of rectangular
174	14	14	targets average Pd
175	33	X²	routine
176	94	+/-	
177	85	+	
178	71	SBR	Call SBR PRT to check
179	99	PRT	limits
180	06	6	
181	49	PRD	6 P(x)
182	28	28	see eq. 24
183	04	4	
184	42	STO	i = 4
185	06	06	Store i in R06
186	76	LBL	Label RAD.
187	70	RAD	
188	02	2	
189	65	×	Call SBR P/R to calcu-
190	71	SBR	late D_i and $P(D_i)$
191	37	P/R	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
192	97	DSZ	If i > 0 subtract 1
193	06	06	from i, store i in
194	70	RAD	R06 and go to RAD
195	76	LBL	Label =.
196	95	=	
197	71	SBR	For i = 0
198	96	WRT	
199	06	6	Repartition back to
200	69	OP	normal partition
201	17	17	
202	36	PGM	Call Pgm. 3 to print
203	03	03	out P
204	71	SBR	
205	03	03	
206	34	34	
207	61	GTO	Go to Label ADV
208	98	ADV	
209	76	LBL	Label EE.
210	52	EE	
211	04	4	Start of elliptical
212	49	PRD	targets average Pd
213	28	28	routine
214	65	×	4P(x)
215	71	SBR	See Eq. 36
216	99	PRT	Call SBR PRT to check
217	33	X^2	limits
218	55	÷	
219	43	RCL	
220	07	07	
221	95	=	
222	48	EXC	Store $\frac{WD^2}{L}$ in R08
223	08	08	
224	33	X^2	See eq. 33
225	94	+/-	
226	85	+	
227	43	RCL	
228	07	07	
229	33	X^2	
230	95	=	
231	34	$\sqrt{x}$	
232	42	STO	Store $\sqrt{L^2-WD^2}$ in R07
233	07	07	
234	08	8	See Eq. 33
235	42	STO	i = 8
236	06	06	Store i in R06
237	76	LBL	Label EXC.
238	48	EXC	Call SBR P/R to calc.
239	71	SBR	D_i and $P(D_i)$
240	37	P/R	See Eq. 36
241	69	OP	
242	36	36	Subtract 1 from i
243	71	SBR	Call SBR P/R to calcu-
244	37	P/R	late D_i and $P(D_i)$
245	65	×	
246	03	3	$4P(D_i)$ for i equal to
247	95	=	1, 3, 5 or 7
248	44	SUM	
249	28	28	
250	97	DSZ	If i > 0 subtract 1
251	06	06	from i, store i in R06
252	48	EXC	and go to EXC
253	02	2	
254	93	.	
255	04	4	Divide R28 by 2.4
256	22	INV	
257	49	PRD	
258	28	28	
259	61	GTO	Go to Label =
260	95	=	
261	76	LBL	Label B.
262	12	B	
263	42	STO	Store S1 in R11
264	11	11	
265	61	GTO	Go to Label WRT
266	96	WRT	
267	76	LBL	Label C.
268	13	C	
269	42	STO	Store WR in R12
270	12	12	
271	61	GTO	
272	96	WRT	Go to Label WRT
273	76	LBL	Label D.
274	14	D	
275	42	STO	Store either S2 or L in
276	13	13	R13
277	61	GTO	
278	96	WRT	Go to Label WRT
279	76	LBL	Label E.
280	15	E	
281	42	STO	Store either S3 or WD
282	14	14	in R14
283	61	GTO	
284	96	WRT	Go to Label WRT
285	76	LBL	Label A'.
286	16	A'	
287	42	STO	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
288	15	15	Store CEP in R15
289	61	GTO	
290	96	WRT	Go to Label WRT
291	76	LBL	Label B'.
292	17	B'	
293	42	STO	Store TR in R16
294	16	16	
295	61	GTO	Go to Label WRT
296	96	WRT	
297	76	LBL	Label D'.
298	19	D'	
299	42	STO	Store sigma in R18
300	18	18	
301	61	GTO	Go to Label WRT
302	96	WRT	
303	76	LBL	Label C'.
304	18	C'	
305	42	STO	Store x in R17
306	17	17	
307	71	SBR	
308	96	WRT	
309	92	RTN	
310	60	DEG	
311	43	RCL	
312	01	01	
313	11	A	
314	16	16	
315	16	16	
316	71	SBR	
317	96	WRT	
318	92	RTN	
319	71	SBR	
320	96	WRT	
321	92	RTN	
322	71	SBR	
323	96	WRT	
324	92	RTN	
325	01	1	
326	01	1	
327	42	STO	
328	00	00	
329	04	4	
330	04	4	
331	36	PGM	
332	03	03	
333	71	SBR	
334	00	00	
335	85	85	

STEP	CODE	KEY	COMMENTS
336	42	STO	
337	28	28	
338	03	3	
339	93	.	
340	02	3	
341	32	X⇄T	
342	43	RCL	
343	00	00	
344	77	GE	
345	91	R/S	
346	43	RCL	
347	28	28	
348	36	PGM	
349	03	03	
350	71	SBR	
351	01	01	
352	66	66	
353	76	LBL	Label ADV.
354	98	ADV	
355	22	INV	Reset Flag 2
356	86	STF	
357	02	02	
358	98	ADV	
359	98	ADV	
360	98	ADV	
361	76	LBL	Label RTN
362	92	RTN	
363	42	STO	Store P in R19
364	19	19	
365	92	RTN	Program stops here
366	43	RCL	Recall 3.n
367	00	00	
368	76	LBL	Label E'.
369	10	E'	
370	42	STO	Start of calculation
371	00	00	Store 3.n in R00
372	22	INV	
373	86	STF	Reset Flag 7
374	07	07	
375	60	DEG	Set degrees angular mode
376	98	ADV	
377	32	X⇄T	
378	04	CLR	Remove pending operations
379	22	INV	
380	58	FIX	
381	03	3	
382	93	.	
383	02	2	

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS
384	77	GE	If 3.n ≤ 3.2 go to
385	36	PGM	Label PGM
386	43	RCL	Recall 3.n
387	00	00	
388	99	PRT	Print 3.n
389	75	-	
390	22	INV	
391	59	INT	
392	42	STO	Store .n in R05
393	05	05	
394	95	=	
395	42	STO	Store 3 in R00
396	00	00	
397	96	STF	Set flag 2
398	02	02	
399	36	PGM	Call Pgm. 3 to print
400	03	03	and check limits on
401	71	SBR	WR, CEP, TR, S and
402	02	02	to calculate eqs. 1
403	24	24	through 20 to get P(x)
404	42	STO	
405	38	38	
406	43	RCL	
407	05	05	
408	44	SUM	Store 3.n in R00 again
409	00	00	
410	76	LBL	Label R/S.
411	91	R/S	
412	01	1	
413	00	0	
414	42	STO	
415	09	09	Call Pgm. 9 to check
416	01	1	limits and print A
417	03	3	
418	36	PGM	
419	09	09	
420	18	C'	
421	43	RCL	
422	05	05	
423	32	X:T	If 3.n = 3.3, go to
424	93	.	Label RST
425	03	3	(Rectangle calculation)
426	67	EQ	
427	81	RST	
428	93	.	If 3.n = 3.5 go to
429	05	5	Label EE (Ellipse
430	67	EQ	calculation)
431	52	EE	

STEP	CODE	KEY	COMMENTS
432	71	SBR	Remove FIX and scientif-
433	96	WRT	ic display format
434	05	5	
435	69	DP	Repartition calculator
436	17	17	to 559.49
437	03	3	
438	06	6	"S" alphanumerics
439	00	0	
440	01	1	
441	42	STO	Store in R07
442	07	07	
443	71	SBR	Call SBR OP to check
444	69	DP	limits and print S1
445	29	CP	
446	71	SBR	Call SBR COS to calcu-
447	39	COS	late D_{12} and $P(D_{12})$
448	69	DP	See eqs. 25 and 32
449	22	22	
450	71	SBR	Call SBR OP to check
451	69	DP	limits and print S2
452	33	X²	
453	42	STO	
454	08	08	Store $(S2)^2$ in R08
455	71	SBR	Call SBR OP to check
456	69	DP	limits and print S3
457	33	X²	
458	42	STO	Store $(S3)^2$ in R09
459	09	09	
460	71	SBR	Calculation of
461	34	FX	
462	95	=	
463	55	÷	See eq. 27
464	02	2	
465	55	÷	
466	43	RCL	
467	11	11	
468	55	÷	
469	43	RCL	
470	14	14	
471	95	=	
472	22	INV	
473	39	COS	
474	32	X:T	Put in t register
475	43	RCL	
476	14	14	
477	71	SBR	Call SBR COS to calcu-
478	39	COS	late D_{23}
479	71	SBR	See eqs. 26 and 32

PROGRAM MEMORY (LIST)

STEP	CODE	KEY	COMMENTS	STEP	CODE	KEY	COMMENTS
480	34	fX	Calculation of ϕ	528	95	=	
481	55	÷		529	55	÷	
482	02	2	See eq. 30	530	43	RCL	
483	95	=		531	11	11	
484	65	×		532	95	=	
485	08	8		533	22	INV	α
486	95	=		534	39	COS	
487	34	fX		535	85	+	Calculation of M
488	32	X↕T		536	38	SIN	
489	03	3		537	32	X↕T	See eq. 29
490	65	×		538	95	=	
491	71	SBR		539	38	SIN	
492	34	fX		540	65	×	
493	95	=		541	02	2	
494	55	÷		542	55	÷	
495	32	X↕T		543	43	RCL	
496	55	÷		544	11	11	
497	43	RCL		545	55	÷	
498	11	11		546	43	RCL	
499	95	=		547	07	07	
500	22	INV		548	32	X↕T	
501	39	COS		549	95	=	
502	42	STO	Store ϕ in R07	550	35	1/X	
503	07	07		551	71	SBR	Call SBR COS to calcu-
504	32	X↕T	Store ϕ in t reg.	552	39	COS	late D_c and $7P(D_c)$.
505	01	1		553	65	×	See eqs. 28 and 32.
506	94	+/-	Calculation of α	554	06	6	
507	49	PRD	See eq. 31	555	95	=	
508	09	09		556	44	SUM	
509	93	.		557	28	28	
510	05	5		558	61	GTO	Go to Label =
511	65	×		559	95	=	
512	71	SBR					
513	34	fX					
514	95	=					
515	94	+/-					
516	65	×					
517	02	2					
518	95	=					
519	34	fX					
520	35	1/X					
521	65	×					
522	53	(					
523	43	RCL					
524	09	09					
525	85	+					
526	43	RCL					
527	08	08					

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