AD A101091

HEADQUARTERS STRATEGIC AIR COMMAND

Directorate of Aircraft Maintenance

Aircraft Engineering Division

Engineering Report No. S-111

NUCLEAR BLAST PROGRAM FOR MINI-CALCULATORS

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REPORT DOCUMENTATION PAGE

REPORT NUMBER

Engineering Report No. S-111

GOVT ACCESSION NO

AD-A101 091

TITLE (and Subtitle)

Nuclear Blast Program for Mini-Calculators

AUTHOR(s)

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PERFORMING ORGANIZATION NAME AND ADDRESS

HQ SAC/LGME
OFFUTT AFB NE 68113

Program Element 11898

CONTROLLING OFFICE NAME AND ADDRESS

HQ SAC/LGME
OFFUTT AFB NE 68113

9 March 1981

NUMBER OF PAGES

15

MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

UNCLASSIFIED

DISTRIBUTION STATEMENT (of this Report)

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DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

KEY WORDS (Continue on reverse side if necessary and identify by block number)

Nuclear Blast, Nuclear Survivability/Vulnerability, Nuclear Criteria, Nuclear Hardness.

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

See Attached

ABSTRACT

A program has been written for the HP-97 (HP-67) minicomputer to solve the blast wave from a nuclear detonation. The program first determines standard-altitude parameters for the altitude of interest. Using these parameters as input, the program then calculates pressures, temperatures, densities, velocities, and Mach Numbers in front and behind the shock. Three subroutines allows the user to input (for any altitude < or = 82,000 ft) a specific overpressure across the shock, a specific gust velocity behind the blast wave, or a specific dynamic pressure behind the blast wave. Corresponding parameters for each input are calculated.

NUCLEAR BLAST PROGRAM

For Mini-Calculators

Introduction

In the process of performing calculations of the values of the pressures, temperatures, velocities, densities, etc. behind weak shock waves at some distance from a nuclear detonation, it became obvious that hand calculation was tedious and interpolation from graphical results subject to error. Therefore a simple program was developed for use on the HP-97 (or HP-67) mini calculator to perform these operations. This program is described in the following narrative.

Although this simple program is not intended to replace the more sophisticated computer codes available for such computation, it is a valuable tool for first cut analyses. It also has the distinct advantage of being highly portable, and serves as handy reference for use when the detailed data are not immediately available.

Discussion

At distances from any nuclear detonation of interest to the analyst working with airborne systems, the blast wave is relatively weak and amenable to solution via standard fluid mechanical equations. The first step in such a solution is the application of standard fluid dynamical equations used to solve the stationary shock. See Figure 1. The governing equations relating conditions in front of and behind the shock can be obtained from any text on supersonic flow. I used Shapiro*.

* A. H. Shapiro, The Dynamics and Thermodynamics of Compressible Fluid Flow. Ronald Press, N.Y. 1953

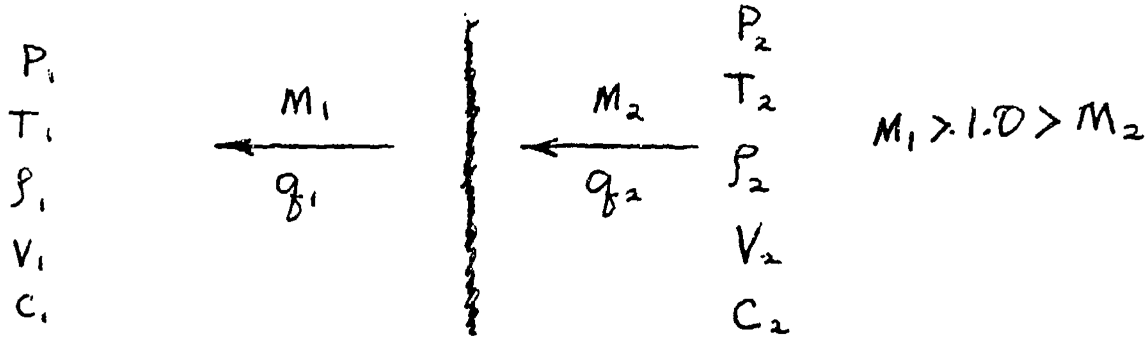

Figure 1. Flow parameters for a stationary shock wave

After solving the stationary shock problem, I then transformed the problem into a moving shock, or blast wave problem by allowing the shock to move with a speed such that its Mach number was equal to M_1. This system uses primed variables and is depicted in Figure 2.

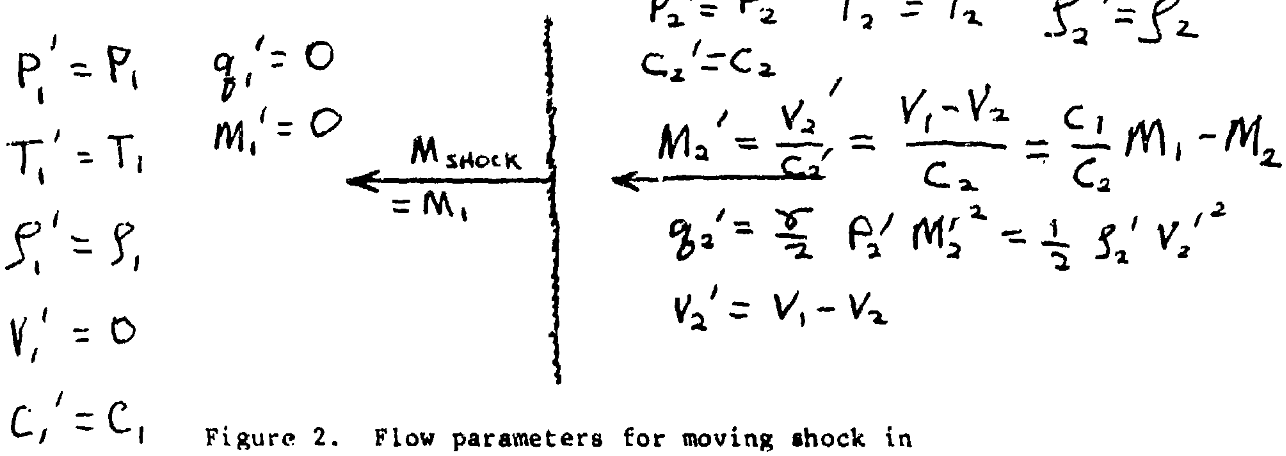

Figure 2. Flow parameters for moving shock in terms of stationary shock solution.

As depicted in Figure 2, the stationary shock solution provides all the data needed to solve the blast wave problem. The parameters of most interest to the nuclear survivability/vulnerability analyst are V_2' (the gust velocity), the overpressure, $(P_2' - P_1' = P_2 - P_1)$ and the dynamic pressure, q_2'.

The program incorporating the solution of the blast wave is listed in the Appendix B and detailed operating instructions are contained in Appendix A. The "guts" of the program is subroutine B, which solves the stationary shock then utilizes that solution to solve the blast wave (moving shock) for any selected altitude and overpressure. Subroutines C and D accept gust velocity and dynamic pressure inputs respectively and iterate back through the basic part of subroutine B until the calculated quantity is within the acceptable tolerance of the input.

Subroutine A is the cornerstone of the program. It contains analytical expressions describing the variation of the standard atmosphere with altitude as presented in Dommasch.* For the specified altitude these equations are solved, resulting in ratios of the values of the parameter of interest at altitude to the sea level standard value. Multiplication of these ratios by the pertinent sea level standard results in the desired value at altitude. These values are stored and also used in subsequent calculations. Note that because of program step limitations, the program was separated into two parts. Part 1 is pertinent for the troposphere ($h \leq$ 36,000 feet) while part 2 is accurate in the stratosphere ($36{,}000 < h \leq$ 82,000) where the temperature is constant with altitude.

CONCLUSION

The program presented herein should prove to be a valuable tool to analysts dealing with weak blast waves of any type, but should prove of particular interest to nuclear survivability/vulnerability analysts in government and industry.

*D. O. Dommasch, S.S. Sherby, and T.F. Connolly, Airplane Aerodynamics, Pitman Publishing Corp. N.Y. 1961.

Appendix A

OPERATING INSTRUCTIONS

NUCLEAR BLAST PROGRAM

I. Subroutine A, Calculation of Ambient Atmospheric Parameters.

Upon loading the program, the first step must be the utilization of Subroutine A to calculate the ambient static pressure and temperature at the altitude of interest. The other subroutines use these parameters, and will not function unless the calculations are made. Note: Load Part 1 if altitude of interest is 36,000 feet or less, load Part 2 if the altitude of interest is between 36,000 and 82,000 feet.

PRESS A - This step clears all registers and sets up the program.

ENTER ALTITUDE - Altitude is in feet.

PRESS R/S - Calculation requires a few seconds. When the altitude is displayed, calculations are complete. Secondary registers contain results of the calculations.

SECONDARY REGISTERS

0	1	2	3	4	5	6	7	8	9
θ (T/T_0)	δ (P/P_0)	σ (ρ/ρ_0)	T °R	P (psia)	ρ (slugs/ft^3)	C (ft/sec)	—	—	h (feet)
—*	δ (P/P_0)	σ (ρ/ρ_0)	T** (°R)	P (psia)	ρ (slugs/ft^3)	—	—	—	h (feet)

* θ = constant = 390°R/518°R

** T = constant = 390 °R

To recall these parameters, press f, then P⇄S. Use RCL for register of interest. Prior to use of other subroutines either restore the original configuration (f, P⇄S) or restart program.

II. Subroutine B - Calculation of Gust Velocity (given an Overpressure).

This subroutine accepts an overpressure (in psi) and solves the blast wave. The gust velocity is displayed at the completion of the calculations. (Recall that Subroutine A must be exercised at least once prior to use of this subroutine. The results of the subroutine are pertinent only for the last altitude entered in Subroutine A.)

PRESS B	Initializes subroutine
ENTER OVERPRESSURE	in psi. Recall overpressure = $P_2 - P_1$.
PRESS R/S	After calculations are complete, gust velocity is displayed.

At the point the user has several options. If the gust velocity corresponding to the selected overpressure for a different altitude is desired, press A, enter the new altitude, press R/S, then exercise subroutine B again. If various overpressure/gust velocity pairs are desired for the selected altitude, it is not necessary to recalculate the atmospheric parameters, press B, then enter the overpressure. The corresponding gust is displayed.

III. Subroutine C. Calculation of Overpressure (given a gust velocity).

This subroutine accepts a gust velocity (in feet/second) and calculates the corresponding overpressure via iteration through the basic solution incorporated in subroutine B. This subroutine may be exercised immediately after the altitude computations, or the completion of any of the other subroutines.

PRESS C	Initializes subroutine
ENTER GUST VELOCITY	feet/second
PRESS R/S	Several iterations may be necessary for convergence. After the calculations are complete, the overpressure is displayed.

If other gust velocity/overpressure pairs are desired for the same altitude, simply repeat the above steps. If a new altitude is desired, subroutine A must be reaccomplished prior to initialization of subroutine C.

IV. Subroutine D. Calculation of the Overpressure and Gust Velocity (given a dynamic pressure).

This subroutine accepts a dynamic pressure in psi and calculates the corresponding overpressure and gust velocity via interation. This subroutine may be exercised immediately after the completion of subroutine A, or upon completion of any of the other subroutines.

PRESS D	Initializes subroutine.
ENTER DYNAMIC PRESSURE	in psi. NOTE. A maximum of 3 places after the decimal will be tolerated --- otherwise program cycles endlessly.
PRESS R/S	Several iterations may be required for convergence after calculations are complete, overpressure is displayed.
PRESS R/S	Gust velocity is displayed.

V. Miscellaneous Notes

1. If the program cycles endlessly, or if an error is indicated in the display, press A twice to clear.

2. The exercise of subroutines B, C, and D results in much data being generated. In each case, only one (or two for D) parameters are displayed, but other shock wave solutions are stored and may be recalled, if they are needed. The register contents are depicted below. Variable labels are from figures 1 and 2.

PRIMARY REGISTERS

A	B	C	D	E	1	2	3	4	5	6	7	8	9	0
P_1	OP	T_1	M_1^2	M_2^2	T_2/T_1	P_2/P_1	ρ_2/ρ_1	c_2/c_1	V_2/V_1	M_2'	V_2'	q_2'	h	—
(psia)	(psi)	(°R)	—	—	—	—	—	—	—	—	(ft/sec)	(psi)	(ft)	—

Appendix B

PROGRAM LISTING

I Part 1

ØØ1	*LBLA	21 11
ØØ2	RCL9	36 Ø9
ØØ3	CLRG	16-53
ØØ4	P S	16-51
ØØ5	CLRG	16-53
ØØ6	R/S	51
ØØ7	STO9	35 Ø9
ØØ8	6	Ø6
ØØ9	.	-62
Ø1Ø	8	Ø8
Ø11	7	Ø7
Ø12	5	Ø5
Ø13	EEX	-23
Ø14	6	Ø6
Ø15	CHS	-22
Ø16	x	-35
Ø17	CHS	-22
Ø18	1	Ø1
Ø19	+	-55
Ø2Ø	STOØ	35 ØØ
Ø21	4	Ø4
Ø22	.	-62
Ø23	2	Ø2
Ø24	5	Ø5
Ø25	6	Ø6
Ø26	1	Ø1
Ø27	Y^x	31
Ø28	STO2	35 Ø2
Ø29	ROLØ	36 ØØ
Ø3Ø	5	Ø5
Ø31	.	-62
Ø32	2	Ø2
Ø33	5	Ø5
Ø34	6	Ø6
Ø35	1	Ø1
Ø36	Y^x	31
Ø37	STO1	35 Ø1
Ø38	RCLØ	36 ØØ
Ø39	5	Ø5
Ø4Ø	1	Ø1
Ø41	8	Ø8
Ø42	x	-35
Ø43	STO3	35 Ø3
Ø44	RCL1	36 Ø1
Ø45	1	Ø1
Ø46	4	Ø4
Ø47	.	-62
Ø48	7	Ø7
Ø49	x	-35
Ø5Ø	STO4	35 Ø4
Ø51	RCL2	36 Ø2
Ø52	.	-62
Ø53	Ø	ØØ
Ø54	Ø	ØØ
Ø55	2	Ø2
Ø56	3	Ø3
Ø57	7	Ø7
Ø58	8	Ø8
Ø59	x	-35
Ø6Ø	STO5	35 Ø5
Ø61	RCL3	36 Ø3
Ø62	X	54
Ø63	4	Ø4
Ø64	9	Ø9
Ø65	x	-35
Ø66	STO6	35 Ø6
Ø67	RCL3	36 Ø3
Ø68	STOC	35 13
Ø69	RCL4	36 Ø4
Ø7Ø	STOA	35 11
Ø71	RCL9	36 Ø9
Ø72	P S	16-51
Ø73	STO9	35 Ø9
Ø74	*LBLB	21 12
Ø75	R/S	51
Ø76	STOB	35 12
Ø77	*LBL2	21 Ø2
Ø78	RCLA	36 11

Ø79	÷	-55	1Ø8	.	-62	137	x	-35
Ø8Ø	STOD	35 14	1Ø9	2	Ø2	138	RCLE	36 15
Ø81	RCLA	36 11	11Ø	x	-35	139	X	54
Ø82	÷	-24	111	1	Ø1	14Ø	-	-45
Ø83	STO2	35 Ø2	112	+	-55	141	STO6	35 Ø6
Ø84	2	Ø2	113	STO1	35 Ø1	142	RCLC	36 13
Ø85	.	-62	114	RCLD	36 14	143	RCL1	36 Ø1
Ø86	4	Ø4	115	.	-62	144	x	-35
Ø87	x	-35	116	2	Ø2	145	X	54
Ø88	.	-62	117	x	-35	146	4	Ø4
Ø89	4	Ø4	118	1	Ø1	147	9	Ø9
Ø9Ø	+	-55	119	+	-55	148	x	-35
Ø91	2	Ø2	12Ø	RCL1	36 Ø1	149	RCL6	36 Ø6
Ø92	.	-62	121	÷	-24	15Ø	x	-35
Ø93	8	Ø8	122	STO1	35 Ø1	151	STO7	35 Ø7
Ø94	÷	-24	123	RCL2	36 Ø2	152	RCLA	36 11
Ø95	STOD	35 14	124	RCL1	36 Ø1	153	RCLB	36 12
Ø96	5	Ø5	125	÷	-24	154	+	-55
Ø97	+	-55	126	STO3	35 Ø3	155	ROL6	36 Ø6
Ø98	STOE	35 15	127	RCL1	36 Ø1	156	X^2	53
Ø99	7	Ø7	128	X	54	157	x	-35
1ØØ	RCLD	36 14	129	STO4	35 Ø4	158	.	-62
1Ø1	x	-35	13Ø	RCL3	36 Ø3	159	7	Ø7
1Ø2	1	Ø1	131	1/X	52	16Ø	x	-35
1Ø3	-	-45	132	STO5	35 Ø5	161	STO8	35 Ø8
1Ø4	RC	36 15	133	RCL4	36 Ø4	162	RCLØ	36 ØØ
1Ø5	÷	-24	134	1/X	52	163	X=Ø?	16-42
1Ø6	1/X	52	135	RCLD	36 14	164	GSBe 23	16 15
1Ø7	STOE	35 15	136	X	54	165	RCLI	36 46

166	X=Ø?	16 42
167	GSB3	23 Ø3
168	RCL7	36 Ø7
169	*LBLC	21 13
17Ø	R/S	51
171	STOØ	35 ØØ
172	RCL7	36 Ø7
173	X=Ø?	16-42
174	GSBe	23 16 15
175	2	Ø2
176	STOB	35 12
177	1	Ø1
178	Ø	ØØ
179	2	Ø2
18Ø	STO7	35 Ø7
181	*LBLe	21 16 15
182	RCLØ	36 ØØ
183	INT	16 34
184	RCL7	36 Ø7
185	INT	16 34
186	X=Y?	16-33
187	GSBa	23 16 11
188	÷	-24
189	RCLB	36 12
19Ø	x	-35
191	STOB	35 12
192	GSB2	23 Ø2
193	*LBLa	21 16 11
194	Ø	ØØ
195	STOØ	35 ØØ
196	RCLB	36 12
197	*LBLD	21 14
198	R/S	51
199	STOI	35 46
2ØØ	RCLB	36 12
2Ø1	X=Ø?	16-43
2Ø2	2	Ø2
2Ø3	STOB	35 12
2Ø4	GSB2	23 Ø2
2Ø5	*LBL3	21 Ø3
2Ø6	RCLI	36 46
2Ø7	RCL8	36 Ø8
2Ø8	DSP3	-63 Ø3
2Ø9	RND	16 24
21Ø	X=Y?	16-33
211	GSB5	23 Ø5
212	÷	-24
213	X	54
214	RCLB	36 12
215	x	-35
216	STOB	35 12
217	GSB2	23 Ø2
218	*LBL5	21 Ø5
219	Ø	ØØ
22Ø	STOI	35 46
221	RCLB	36 12
222	R/S	51
223	RCL7	36 Ø7
224	R/S	51

I1 Part 2

ØØ1	*LBLA	21 11	Ø27	5	Ø5	Ø53	x	-35
ØØ2	RCL9	36 Ø9	Ø28	3	Ø3	Ø54	STO2	35 Ø2
ØØ3	CLRG	16-53	Ø29		-62	Ø55	.	-62
ØØ4	P S	16-51	Ø3Ø	3	Ø3	Ø56	Ø	ØØ
ØØ5	CLRG	16-53	Ø31	÷	-24	Ø57	Ø	ØØ
ØØ6	R/S	51	Ø32	8	33	Ø58	2	Ø2
ØØ7	STO9	35 Ø9	Ø33	STO7	35 Ø7	Ø59	3	Ø3
ØØ8	3	Ø3	Ø34	.	-62	Ø6Ø	7	Ø7
ØØ9	6	Ø6	Ø35	2	Ø2	Ø61	7	Ø7
Ø1Ø	EEX	-23	Ø36	2	Ø2	Ø62	x	-35
Ø11	3	Ø3	Ø37	3	Ø3	Ø63	STO5	35 Ø5
Ø12	STO8	35 Ø8	Ø38	4	Ø4	Ø64	ROL3	36 Ø3
Ø13	X≤Y?	16-35	Ø39	x	-35	Ø65	STOC	35 13
Ø14	GSB9	23 Ø9	Ø4Ø	STO1	35 Ø1	Ø66	ROL4	36 Ø4
Ø15	Ø	ØØ	Ø41	1	Ø1	Ø67	STOA	35 11
Ø16	÷	-24	Ø42	4	Ø4	Ø68	ROL9	36 Ø9
Ø17	LBL9	21 Ø9	Ø43	.	-62	Ø69	P/S	16-51
Ø18	3	Ø3	Ø44	7	Ø7	Ø7Ø	STO9	35 Ø9
Ø19	9	Ø9	Ø45	x	-35			
Ø2Ø	Ø	ØØ	Ø46	STO4	35 Ø4			
Ø21	STO3	35 Ø3	Ø47	ROL7	36 Ø7			
Ø22	ROL8	36 Ø8	Ø48	.	-62			
Ø23	ROL9	36 Ø9	Ø49	2	Ø2			
Ø24	-	-45	Ø5Ø	9	Ø9			
Ø25	ROL3	36 Ø3	Ø51	7	Ø7			
Ø26	÷	-24	Ø52	1	01			

Remainder of Program is Identical to Part 1.