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

ABSTRACT

ABSTRACT (If necessary, use Block 20, if different from Report)

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 ^{SL or =} 382,000 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-37) 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

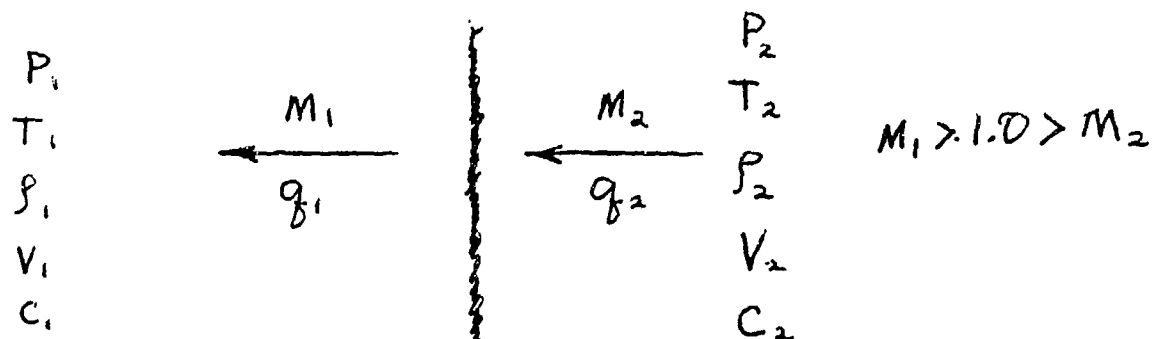


Figure 1. Flow parameters for a stationary shock wave

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.

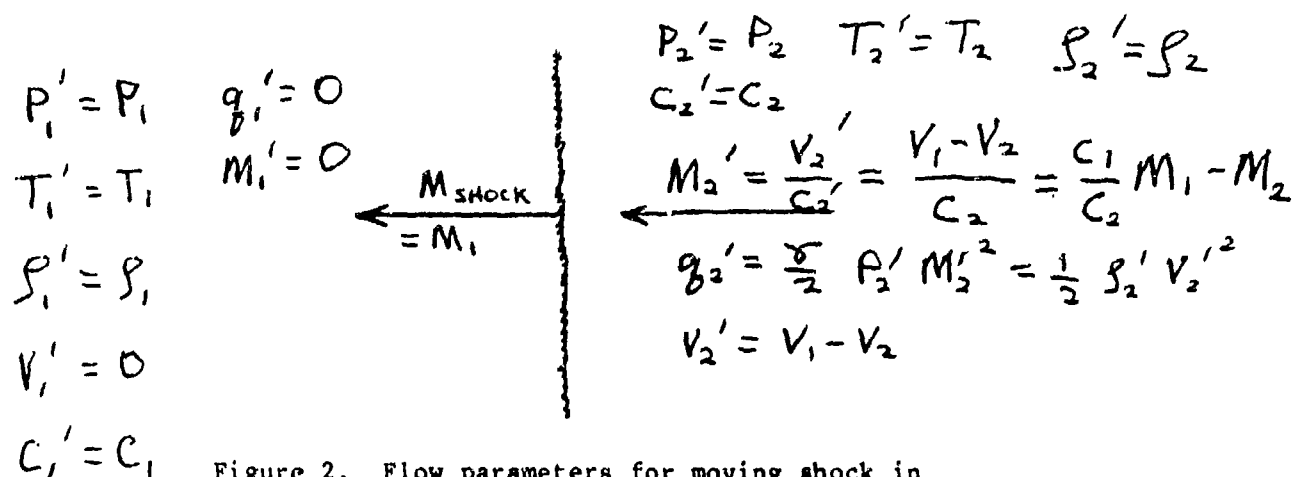


Figure 2. Flow parameters for moving shock in terms of stationary shock solution.

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)	ρ (P/P_0)	σ (ρ/ρ_0)	T ($^{\circ}R$)	P (psia)	ρ (slugs/ft^3)	C (ft/sec)	—	—	h (feet)
*	ρ (P/P_0)	σ (ρ/ρ_0)	T^{**} ($^{\circ}R$)	P (psia)	ρ (slugs/ft^3)	—	—	—	h (feet)

$$* \theta = \text{constant} = 390^{\circ}R / 518^{\circ}R$$

$$**T = \text{constant} = 390^{\circ}R$$

To recall these parameters, press f, then P $\leftrightarrow$ S. Use RCL for register of interest. Prior to use of other subroutines either restore the original configuration (i, P $\leftrightarrow$ 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 iteration. 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_1^2	T_2/T_1	P_2/P_1	ρ_2/ρ_1	C_2/C_1	V_2/V_1	M_2'	V_2'	g_2'	h	-
(psi)	(psi)	(°F)	-	-	-	-	-	-	-	-	(ft/sec)	(psi)	(ft)	-

Appendix B
PROGRAM LISTING

I Part 1

001	*LBLA	21 11	027	Y*	31	053	0	00
002	RCL9	36 09	028	STO2	35 02	054	0	00
003	CLRG	16-53	029	ROL0	36 00	055	2	02
004	P S	16-51	030	5	05	056	3	03
005	CLRG	16-53	031	.	-62	057	7	07
006	R/S	51	032	2	02	058	8	08
007	STO9	35 09	033	5	05	059	x	-35
008	6	06	034	6	06	060	STO5	35 05
009	.	-62	035	1	01	061	RCL3	36 03
010	8	08	036	Y*	31	062	X	54
011	7	07	037	STO1	35 01	063	4	04
012	5	05	038	RCL0	36 00	064	9	09
013	EEX	-23	039	5	05	065	x	-35
014	6	06	040	1	01	066	STO6	35 06
015	CHS	-22	041	8	08	067	RCL3	36 03
016	x	-35	042	x	-35	068	STOC	35 13
017	CHS	-22	043	STO3	35 03	069	RCL4	36 04
018	1	01	044	RCL1	36 01	070	STOA	35 11
019	+	-55	045	1	01	071	RCL9	36 09
020	STO0	35 00	046	4	04	072	P S	16-51
021	4	04	047	.	-62	073	STO9	35 09
022	.	-62	048	7	07	074	*LBLB	21 12
023	2	02	049	x	-35	075	R/S	51
024	5	05	050	STO4	35 04	076	STOB	35 12
025	6	06	051	RCL2	36 02	077	*LBL2	21 02
026	1	01	052	.	-62	078	RCLA	36 11

079	÷	-55	108	.	-62	137	x	-35
080	STOD	35 14	109	2	02	138	RCLC	36 15
081	RCLA	36 11	110	x	-35	139	X	54
082	÷	-24	111	1	01	140	-	-45
083	STO2	35 02	112	+	-55	141	STO6	35 06
084	2	02	113	STO1	35 01	142	RCLC	36 13
085	.	-62	114	RCLD	36 14	143	RCL1	36 01
086	4	04	115	.	-62	144	x	-35
087	x	-35	116	2	02	145	X	54
088	.	-62	117	x	-35	146	4	04
089	4	04	118	1	01	147	9	09
090	+	-55	119	+	-55	148	x	-35
091	2	02	120	RCL1	36 01	149	RCL6	36 06
092	.	-62	121	.	-24	150	x	-35
093	8	08	122	STO1	35 01	151	STO7	35 07
094	÷	-24	123	RCL2	36 02	152	RCLA	36 11
095	STOD	35 14	124	RCL1	36 01	153	RCLB	36 12
096	5	05	125	.	-24	154	+	-55
097	+	-55	126	STO3	35 03	155	ROL6	36 06
098	STOE	35 15	127	RCL1	36 01	156	X ²	53
099	7	07	128	X	54	157	x	-35
100	RCLD	36 14	129	STO4	35 04	158	.	-62
101	x	-35	130	RCL3	36 03	159	7	07
102	1	01	131	1/X	52	160	x	-35
103	-	-45	132	STO5	35 05	161	STO8	35 08
104	RC	36 15	133	RCL4	36 04	162	RCL0	36 00
105	÷	-24	134	1/X	52	163	X=0?	16-42
106	1/X	52	135	RCLD	36 14	164	GSB 23	16 15
107	STOE	35 15	136	X	54	165	RCLI	36 46

166	X=Ø?	16 42	196	RCLB	36 12
167	GSB3	23 Ø3	197	*LBLD	21 14
168	RCL7	36 Ø7	198	R/S	51
169	*LBLC	21 13	199	STOI	35 46
170	R/S	51	200	RCLB	36 12
171	STOØ	35 ØØ	201	X=Ø?	16-43
172	RCL7	36 Ø7	202	2	Ø2
173	X=Ø?	16-42	203	STOB	35 12
174	GSBe	23 16 15	204	GSB2	23 Ø2
175	2	Ø2	205	*LBL3	21 Ø3
176	STOB	35 12	206	RCLI	36 46
177	1	Ø1	207	RCLS	36 Ø8
178	Ø	ØØ	208	DSP3	-63 Ø3
179	2	Ø2	209	RND	16 24
180	STO7	35 Ø7	210	X=Y?	16-33
181	*LBLc	21 16 15	211	GSB5	23 Ø5
182	RCLØ	36 ØØ	212	÷	-24
183	INT	16 34	213	X	54
184	RCL7	36 Ø7	214	RCLB	36 12
185	INT	16 34	215	x	-35
186	X=Y?	16-33	216	STOB	35 12
187	GSBa	23 16 11	217	GSB2	23 Ø2
188	÷	-24	218	*LBL5	21 Ø5
189	RCLB	36 12	219	Ø	ØØ
190	x	-35	220	STOI	35 46
191	STOB	35 12	221	RCLB	36 12
192	GSB2	23 Ø2	222	R/S	51
193	*LBLa	21 16 11	223	RCL7	36 Ø7
194	Ø	ØØ	224	R/S	51
195	STOØ	35 ØØ			

Il Part 2

001	*LBLA	21 11	027	5	05	053	x	-35
002	RCL9	36 09	028	3	03	054	STO2	35 02
003	CLRG	16-53	029		-62	055	.	-62
004	P S	16-51	030	3	03	056	0	00
005	CLRG	16-53	031	÷	-24	057	0	00
006	R/S	51	032	8	33	058	2	02
007	STO9	35 09	033	STO7	35 07	059	3	03
008	3	03	034	.	-62	060	7	07
009	6	06	035	2	02	061	7	07
010	BEX	-23	036	2	02	062	x	-35
011	3	03	037	3	03	063	STO5	35 05
012	STO8	35 08	038	4	04	064	ROL3	36 03
013	X<Y?	16-35	039	x	-35	065	STOC	35 13
014	GSB9	23 09	040	STO1	35 01	066	ROL4	36 04
015	0	00	041	1	01	067	STOA	35 11
016	.	-36	042	4	04	068	ROL9	36 09
017	LBL9	21 09	043	.	-62	069	P/S	16-51
018	3	03	044	7	07	070	STO9	35 09
019	9	09	045	x	-35			
020	0	00	046	STO4	35 04			
021	STO3	35 03	047	ROL7	36 07			
022	ROL8	36 08	048	.	-62			
023	ROL9	36 09	049	2	02			
024	-	-45	050	9	09			
025	ROL3	36 03	051	7	07			
026	÷	-24	052	1	01			

Remainder
of
Program
is
Identical
to
Part 1.