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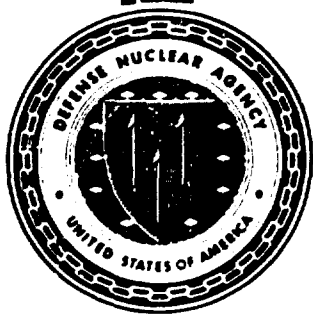
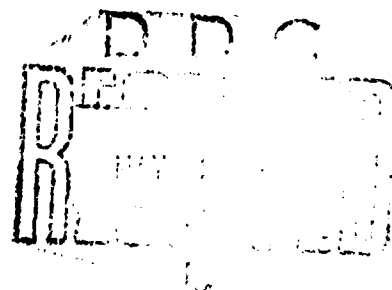
DNA 2714T

July 1971

THE VARIATION OF SHOCK FRONT PROPERTIES FROM A 1-KT. EXPLOSION WITH ALTITUDE

Edward J. Kownacki

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This work was done at the request of and under the general direction of Mr. Jack R. Kelso.
The advice and assistance of Mr. Louis J. Belliveau is acknowledged.

ABSTRACT

A computer program was developed to present shock front properties in the form of isovalues as functions of altitude of burst and range. This program consisted of a Sachs' scaling routine and a log-log interpolation routine. It was found that overpressure, density, and Rho-U decrease with increasing altitude; particle velocity, density ratio, pressure ratio, and shock strength increase with increasing altitude; thermal flux density and dynamic pressure remain relatively unchanged with increasing altitude.

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SECTION 1

INTRODUCTION

The standard scientific presentation of weapons effects information is in the form of universal curves as in NOLTR-69-88¹ and EM-1.² For engineering purposes a presentation in the form of isovalues in the desired quantities on a chart of altitude and damage ranges may provide a more significant insight into the altitude dependence of isovalue ranges. The obtaining of these preselected isovalues is a standard and somewhat tedious problem in cross plotting and interpolation. Sachs' scaling and interpolation computer routines were obtained from NOL³ and modified to incorporate logarithmic interpolation.

¹ Lehto, E. L., and Larson, R. A. "Long Range Propagation of Spherical Shock Waves from Explosions in Air." NOLTR-69-88. (Unclassified)

² "Capabilities of Nuclear Weapons." EM-1. (Confidential)

³ Lehto, D. L., various private communications on computer programs for Sachs' scaling and interpolation schemes.

SECTION 2

DISCUSSION

2-1. GENERAL. Damage to aeronautical and missile systems within the sensible atmosphere (0 to 100,000 feet altitude) from nuclear weapons effects is expressible in terms of damage distances for damage environments, such as overpressure, dynamic pressure, thermal radiation, neutron and X-ray flux, etc. For some systems the dominant or largest damage distances are associated with hydrodynamic shock front properties or thermal radiation. These systems are generally aerodynamic vehicles, such as aircraft, cruise missiles, and low-altitude-point defense missiles, such as the 3T's, Nike, or Sprint.

2-2. SHOCK FRONT PROPERTIES. The hydrodynamic shock front properties of interest to aerodynamic vehicles can be defined by a system consisting of a sea-level, 1-kt. pressure-distance curve and a means of obtaining altitude and yield corrections to this basic curve.

2-3. THERMAL FLUX DENSITY. The thermal flux density (Q) is defined by the formula $Q = fWc/R^2$, where R is the range, f is the thermal partition function, W is the yield, and c is a constant containing dimension factors and the transparency factor (T) of the atmosphere (in our case $T = 1$, perfect transparency).

2-4. STANDARD 1-KT. NUCLEAR FREE AIR PRESSURE-DISTANCE CURVE FOR SEA-LEVEL CONDITIONS. The data for the 1 kt., sea-level overpressure curve was provided by two sources:

above 60 p.s.i., US59 (DASA 1200)

below 60 p.s.i., NOLTR 69-88.

This data is listed as Subroutine RP1271 and plotted in figure 2-1.

2-5. STANDARD 1-KT. NUCLEAR THERMAL FLUX-DISTANCE CURVE FOR SEA-LEVEL CONDITIONS. The thermal flux density formula used was $Q = 7.96 fW/R^2$, where 7.96 includes the transparency factor (T), the dimensionless factor $\frac{1}{4\pi}$, and the unit factor to give Q in terms of cal./cm.². The sea-level, 1-kt. thermal flux density is found plotted in figure 2-2.

2-6. ALTITUDE CORRECTIONS-SACHS' SCALING. The altitude corrections applied are the usual Sachs' scaling relationships:

$$\frac{\Delta P_1}{P_1} = \frac{\Delta P_2}{P_2}$$

When:

$$R_1 \left[\frac{P_1}{W_1} \right]^{1/3} = R_2 \left[\frac{P_2}{W_2} \right]^{1/3}$$

Where:

ΔP_1 and ΔP_2 are overpressures for point 1 and point 2, respectively, P_1 and P_2 are the respective atmospheric pressures, R_1 and R_2 are the respective ranges, and W_1 and W_2 are the respective yields.

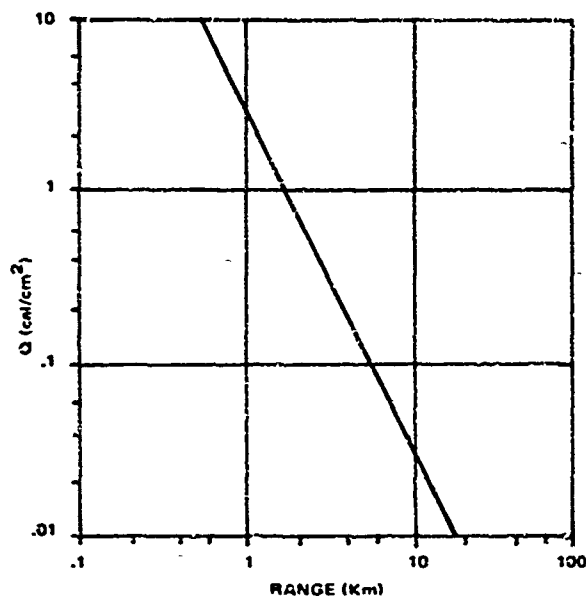


Figure 2-1. --1-kt., sea-level overpressure curve
in the range 1,700 to 0.00016 p. s. i.

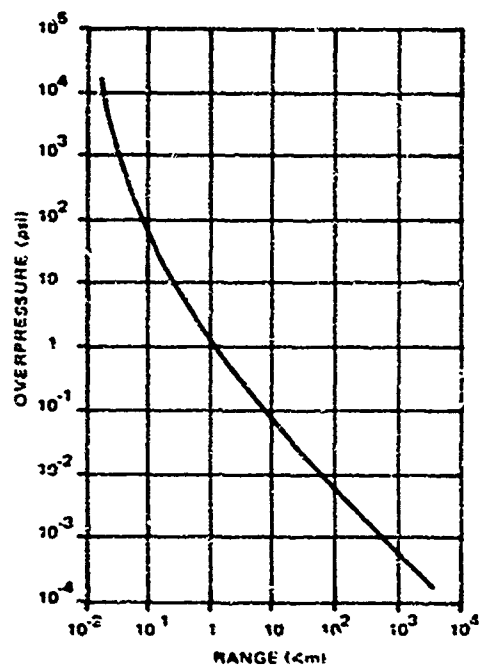


Figure 2-2. --1-kt. thermal flux curve
for sea-level conditions.

2-6.1 Subroutine ARDC provides pressure, temperature, and density of the standard atmosphere. The data was provided by R. A. Minzer, K. S. W. Champion, and H. L. Pond in "The ARDC Model Atmosphere," 1959, Air Forces Surveys in Geophysics No. 115 (AFCRC-TR-59-267), Air Force Cambridge Research Center, August 1959.

2-6.2 Using the overpressure-range curve of Subroutine RP1271 as the base curve, and the atmospheric pressures generated by subroutine ARDC, the overpressures for any altitude and any corrected yield (in this exercise $W_1 = W_2$) can be calculated.

2-7. ENERGY PARTITION FOR BLAST AND THERMAL AS A FUNCTION OF ALTITUDE. The yield corrections which are applied are obtained from the more formally correct radiation-hydrodynamic computer code calculations. These corrections are, unfortunately, functions of yield, distance, and altitude; but, for the range of hydrodynamic front and thermal radiation variables of interest in this memorandum, the yield correction is assumed to be a simple function of altitude only. The simplifications used in this memorandum are straight-line approximations to the curves presented in EM-1, and are applied first to the overpressure dependent qualities, and then independently to the thermal radiation.

2-7.1 The blast yield reduction with altitude function was taken from the effects manual, "Capabilities of Nuclear Weapons," 1 January 1968, and the thermal partition function was taken from chapter 3, "Thermal Radiation Phenomena," KN-68-504(R), 26 May 1969. These two functions are found plotted as figures 2-3 and 2-4. Also plotted are the straight-line approximations which were used in the computer program.

2-7.2 These straight-line approximations were used mainly for the purpose of facilitating computer time. There is no simple functional dependence between altitude and the quantities, and so to avoid feeding in all the data points for every possible altitude, the straight-line approximation was adopted.

2-7.3 For the blast yield reduction curve, the greatest difference occurs around 80 kft., where there is a difference of 0.02 (approximately 2-percent error) between the curve and the approximation. The curve and the approximation agree quite well over the whole altitude range, the error being less than 1 percent over most of the range.

2-7.4 The blast yield reduction curve can be compared with a plot of the maximum computed effective blast yield in DASA 1200. This plot is shown in figure 2-5. The straight-line approximation used in the program was fitted to the curve, not to the envelope of figure 2-5, because in the altitude range of interest there are only two computations (at 105 kft.), and the curve intersects these points while the envelope does not. The function used is considered conservative for defense purposes, as in sure-survival studies on aircraft.

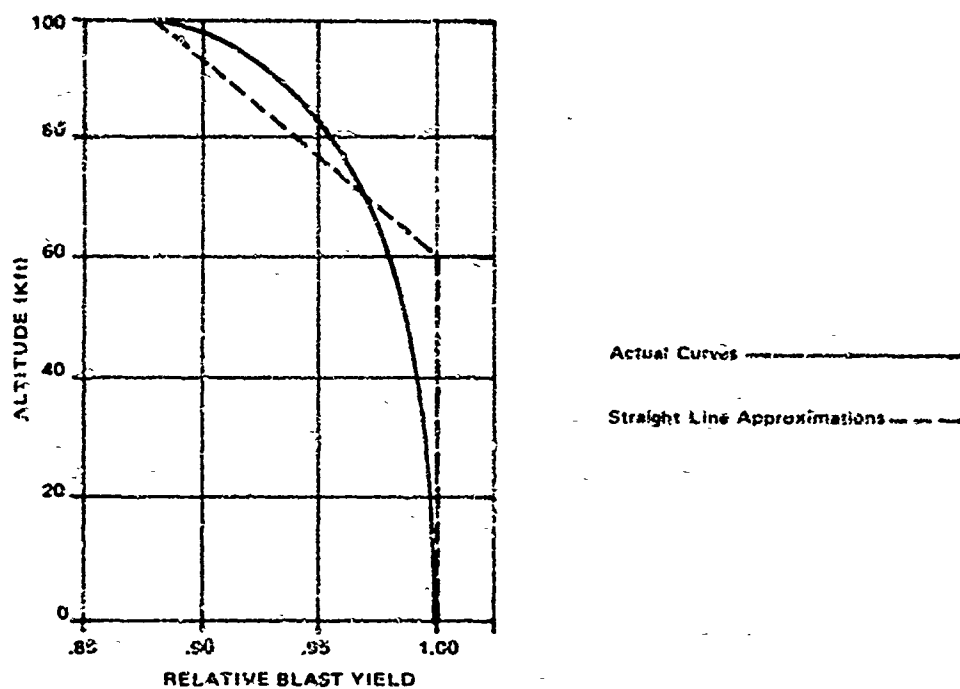


Figure 2-3. -- Blast yield reduction with altitude.

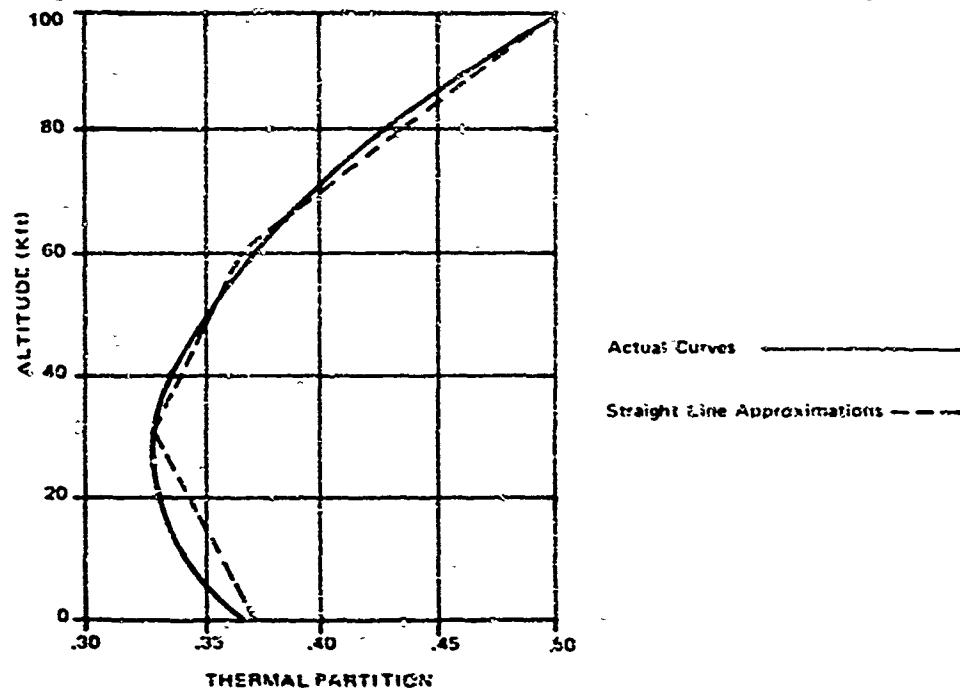


Figure 2-4. -- Thermal partition function for 1 kt.

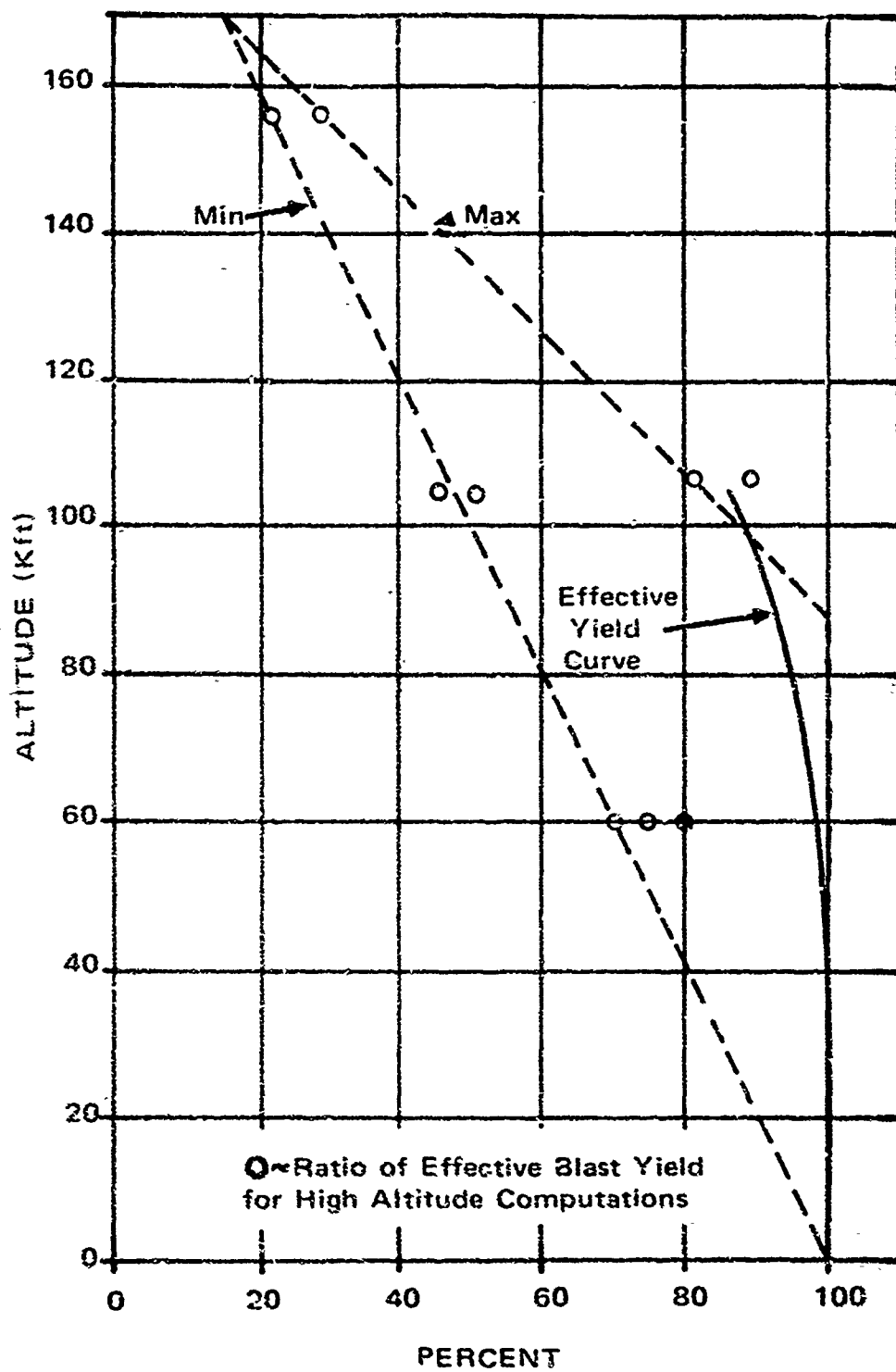


Figure 2-5. -- Effective blast yield versus burst altitude.

2-7.5 For the thermal partition function, the greatest difference occurs around 20 kft., where there is a difference of 0.01 (approximately 2-percent error) between the curve and the approximation. For the majority of altitudes, the error is less than 1 percent.

2-8. PRESENTATION OF SHOCK FRONT PROPERTIES (RANKINE-HUGONOT RELATIONS) VERSUS ALTITUDE CURVES AND THERMAL FLUX DENSITY VERSUS ALTITUDE CURVES.

The Rankine-Hugonot relations⁴ enable the calculation of density, density ratio, particle velocity, pressure ratio, shock strength, and dynamic pressure behind the shock front if the peak overpressure is given.

2-8.1 The program presented is not the most efficient program because a slight rearrangement of cards is necessary when changing from interpolation of one quantity to another (i.e., overpressure to dynamic pressure, density to thermal flux density, etc.). The card rearrangement is simple and straightforward and preferable to one gigantic, complex program that would just be nine programs added together. This simple card rearrangement can be seen in the sample programs presented in appendix II.

2-8.2 The peak overpressure isovalues are presented in figure 2-6, the dynamic pressure isovalues in figure 2-7, the particle velocity in figure 2-8, the density ratio in figure 2-9, the particle velocity $\times$ density (ρU) in figure 2-10, the pressure ratio in figure 2-11, the shock strength in figure 2-12, and the density in figure 2-13.

2-8.3 All quantities were plotted from sea level to 100-kft. altitude, except for density, which is plotted only from sea level to 40 kft. in the most advantageous cases. The reason for this can be discerned by doing a few simple calculations.

2-8.4 The formula for density is $DENSITY = 0.076475 \times DRATIO \times \frac{7 + 6 POVPA}{7 + POVPA}$ where $POVPA = \frac{OVP}{PSIAMB}$. Since $DRATIO = 1$ at sea level, the minimum and maximum values of $DENSITY$ are entirely dependent on the theoretical limits of OVP .

$$\text{If } OVP = 0, DENSITY = 0.076475$$

$$\text{If } OVP = \infty, DENSITY = 0.076475 \times 6 = 0.45885$$

$$\text{At 50 kft., } DRATIO = \frac{0.011709}{0.076475}$$

Therefore, if $OVP = \infty$, $DENSITY = 0.076475 \times \frac{0.011709}{0.076475} \times 6 = 0.070254$.

2-8.5 Since the highest possible value of $DENSITY$ at 50 kft. is less than the lowest possible value of $DENSITY$ at sea level, it is impossible to produce a plot that will have an altitude dependence from sea level to greater than 40 kft.

2-8.6 The thermal flux density isovalues are presented in figure 2-14.

⁴ Glasstone, S. (ed.). "The Effects of Nuclear Weapons." 1964.

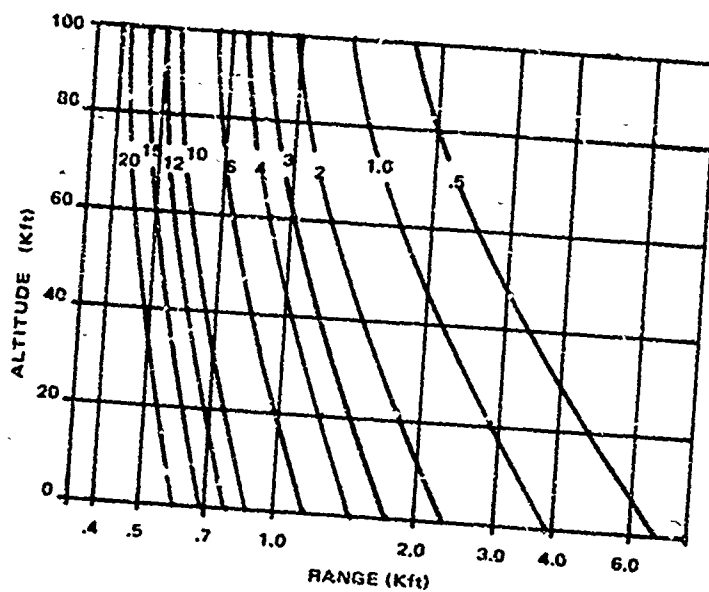


Figure 2-6. -- Free-field overpressure (p. s. i.) as a function of altitude and range.

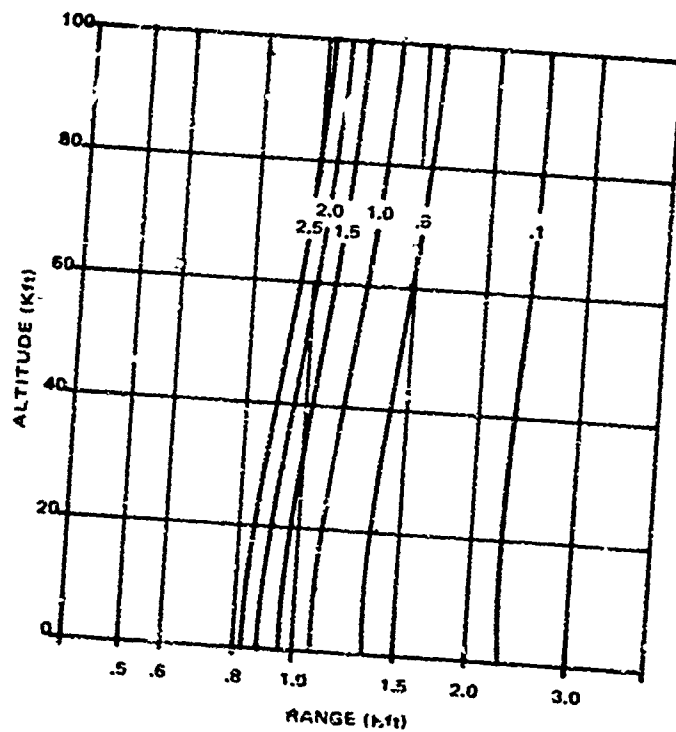


Figure 2-7. -- Dynamic pressure (p. s. i.) as a function of altitude and range.

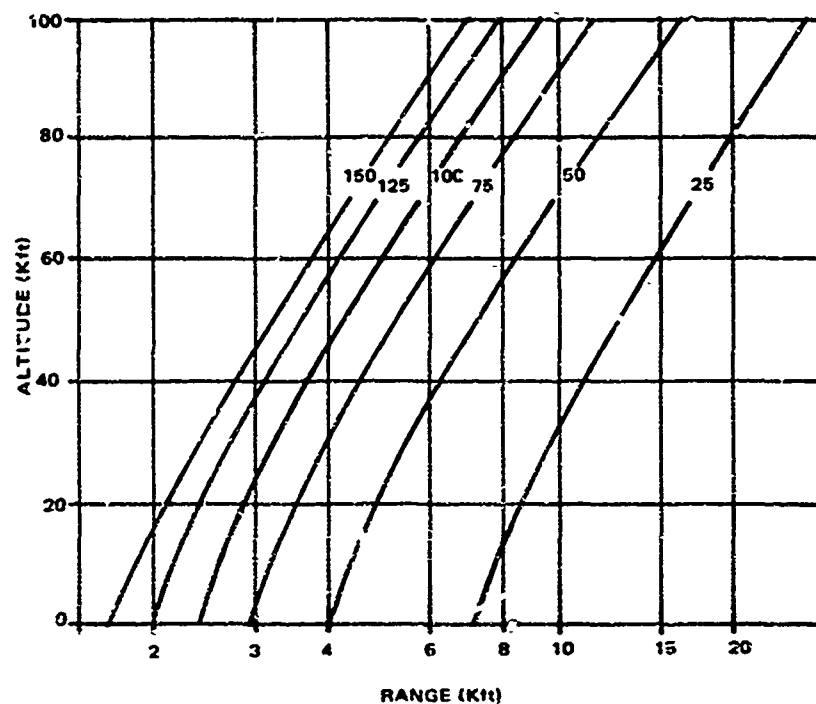


Figure 2-8. -- Particle velocity (ft./sec.) as a function of altitude and range.

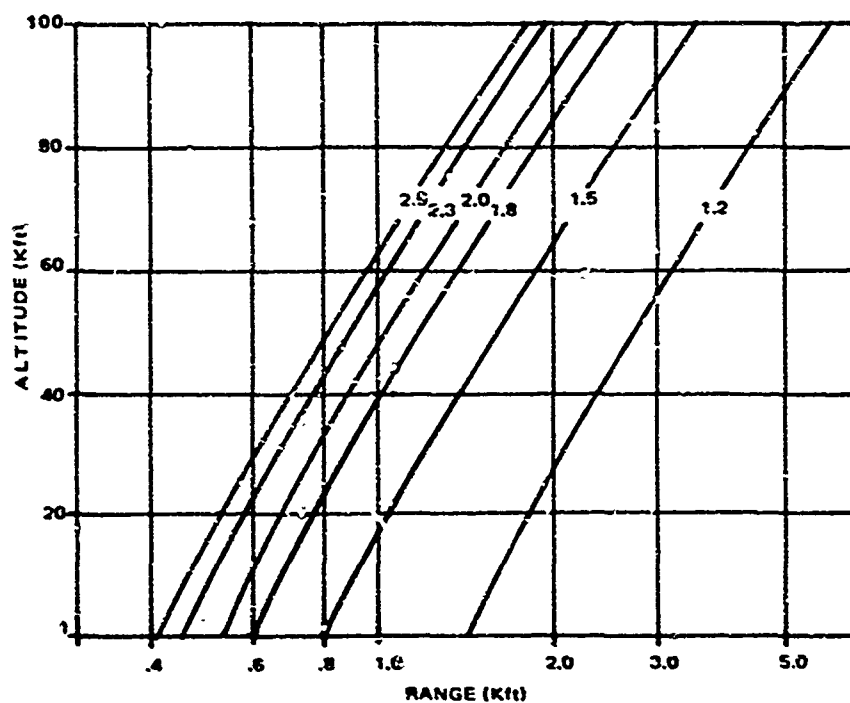


Figure 2-9. -- Density ratio as a function of altitude and range.

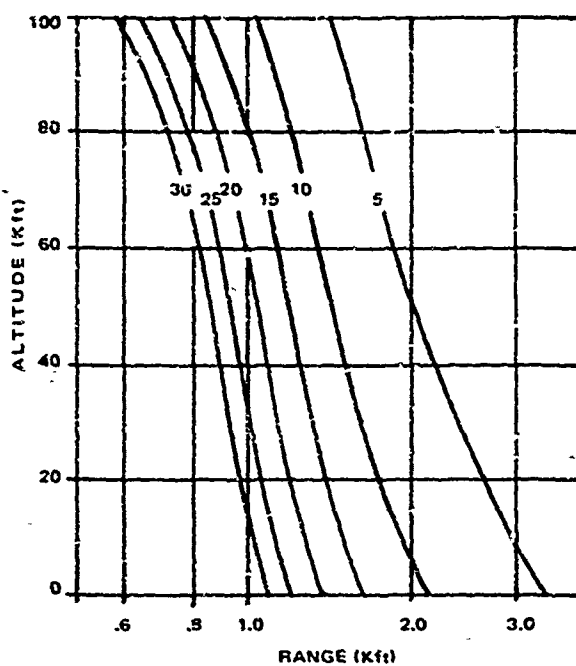


Figure 2-10. -- Rho-U (slugs/(in.²-sec.)) as a function of altitude and range.

ALT = 0 KFT

OVERPRESSURE	PRESSURE RATIO
83.8 psi	5.7
35.3 "	2.4
19.1 "	1.3
9.71 psi	.66
5.88 "	.40
.97 "	.066

$$\text{Pressure Ratio} = \frac{\text{Overpressure}}{\text{Ambient Pressure}}$$

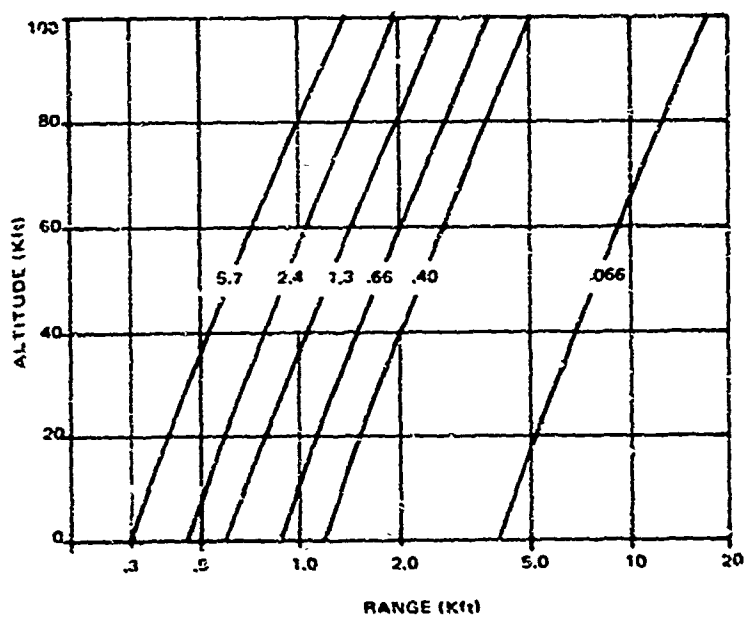


Figure 2-11. -- Pressure ratio as a function of altitude and range.

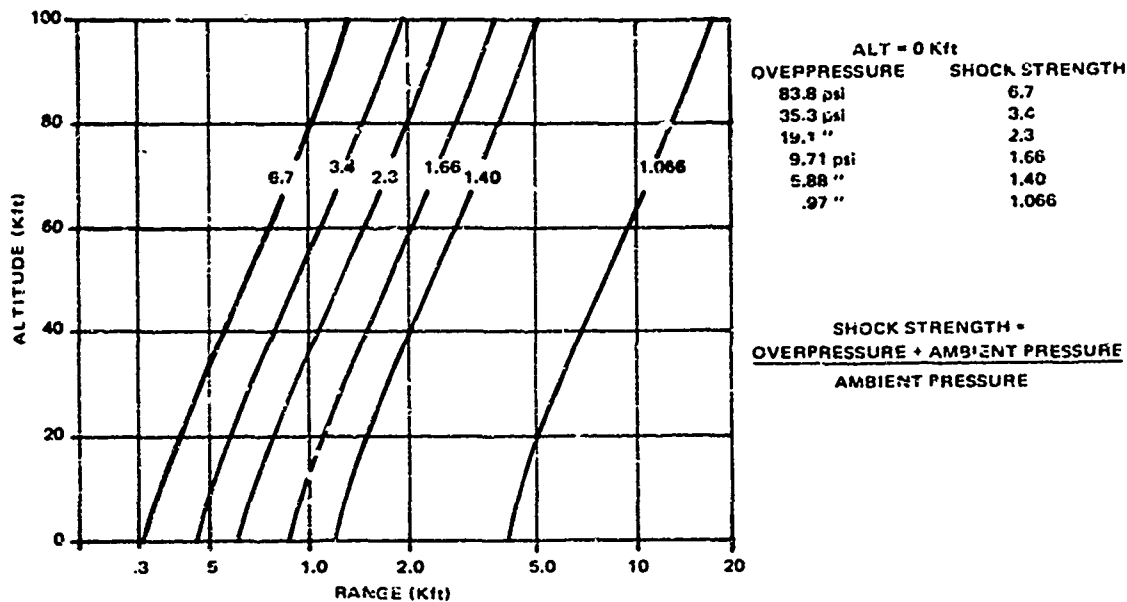


Figure 2-12. -- Shock strength as a function of altitude and range.

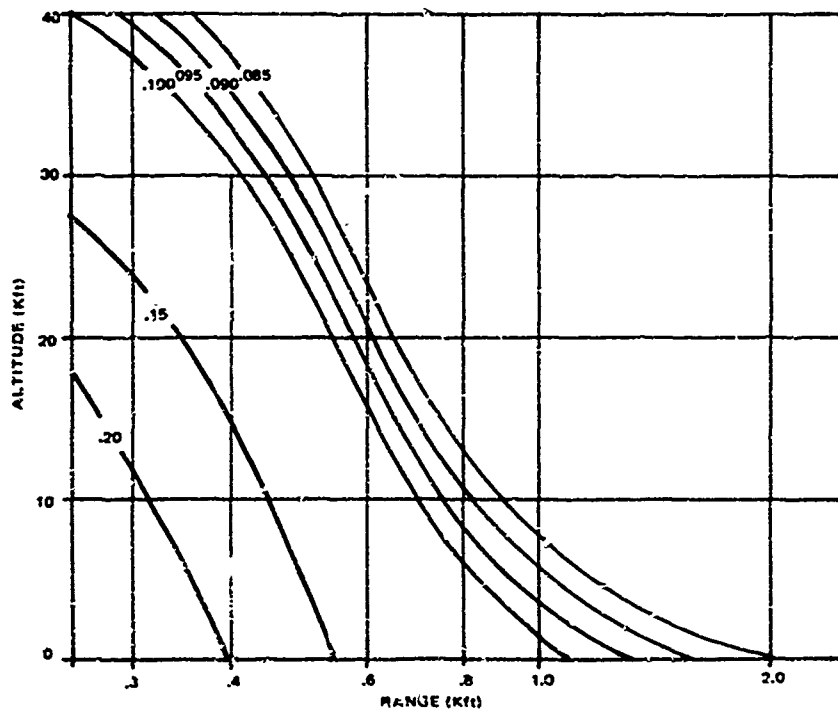


Figure 2-13. -- Density (slugs/(ft. -in.²)) as a function of altitude and range.

2-9. YIELD CORRECTIONS. Distance approximations for values of yield other than those presented in this memorandum may be obtained by multiplying the range by the cube root of the yield for hydrodynamic properties and the square root of the yield for thermal radiation. Discrepancies in the yield-correction factors are masked somewhat by the cube root and square root dependence, but very large yield variations may require more accurate estimates of the yield-corrections factor as presented in EM-1.

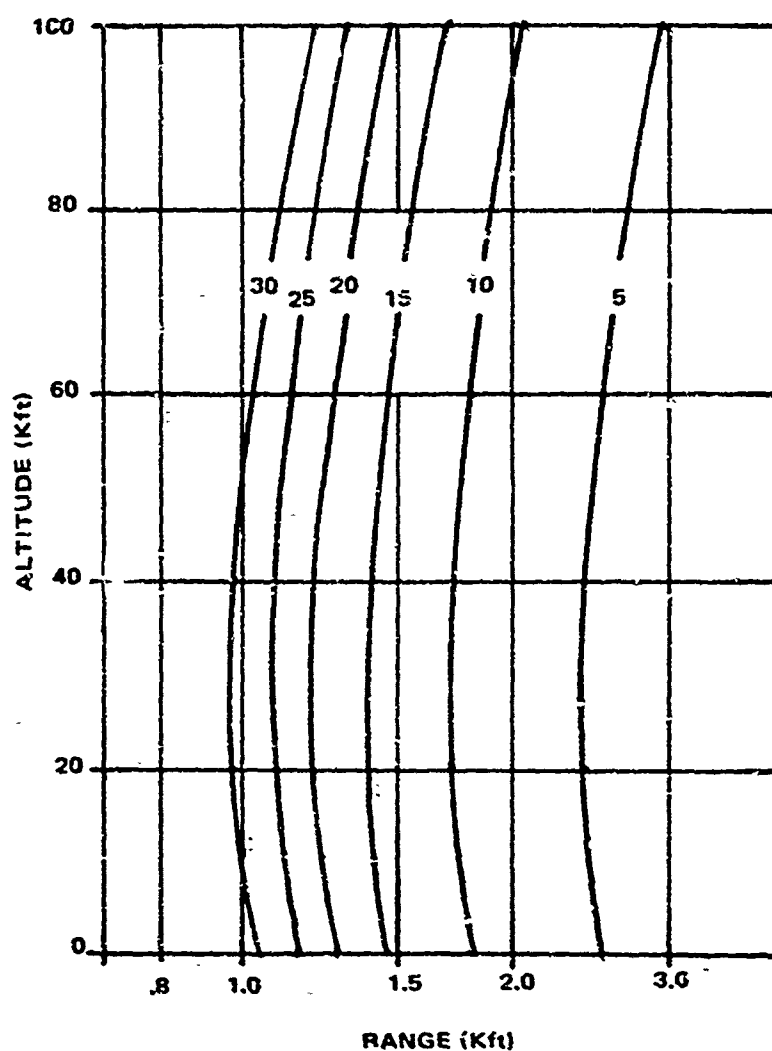


Figure 2-14. -- Thermal flux density (cal./cm.²) as a function of altitude and range.

SECTION 3

CONCLUSIONS

3-1. It is found that overpressure, density, and Rho-U decrease with increasing altitude; particle velocity, pressure ratio, shock strength, and density ratio increase with increasing altitude; thermal flux density and dynamic pressure remain relatively unchanged with increasing altitude.

3-2. This type of presentation should be very useful in determining approximate sure-kill and/or sure-survival ranges for the various aerodynamic vehicles. By placing the various isovalues on a single chart, a sure-kill envelope could be drawn for the range 0 to 100,000 feet. For example, if the sure-kill criteria is an overpressure of 2 p.s.i., a particle velocity of 100 ft./sec., or a thermal flux density of 20 cal./cm.², and a sure-survival criteria is an overpressure of 1 p.s.i., a particle velocity of 50 ft./sec., or a thermal flux density of 10 cal./cm.², then the determining sure-kill/sure-survival range for a 1-kt. explosion is entirely dependent on the particle velocity, as shown in figure 3-1.

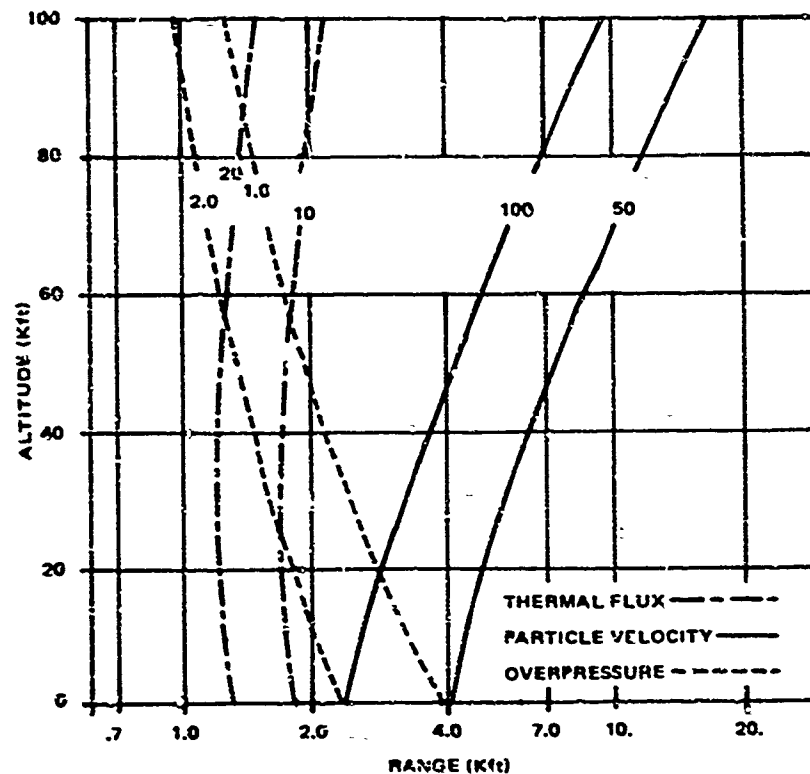


Figure 3-1. -- Free-field overpressure (p.s.i.), thermal flux density (cal./cm.²), and particle velocity (ft./sec.) for 1 kt.

SECTION 4

BIBLIOGRAPHY

1. "Nuclear Weapons Blast Phenomena." US59 (DASA 1200), March 1960.
2. "Long Range Propagation of Spherical Shockwaves from Explosions in Air." NOLTR 69-88, 22 July 1969.
3. Effects manual, "Capabilities of Nuclear Weapons." 1 January 1968.
4. "Thermal Radiation Phenomena." KN-68-504(R), Chapter 3, 26 May 1969.
5. "The ARDC Model Atmosphere." Air Force Surveys in Geophysics No. 115 (AFCRC-TR-59-267), 1959.

APPENDIX I

INTERPOLATION SCHEME

The interpolation scheme used is a straight-line approximation scheme; i. e., it is assumed that in a well-behaved region of a curve, two points can be chosen, and the straight line defined by these points can be used to generate a value of R that will approach the desired value of R . By repeated use of this scheme, the desired value of R can be approached to within any desired accuracy. The program actually used an accuracy of 0.1 percent in R .

An initial value of R_1 is chosen, and then R_2 is chosen to be equal to $2R_1$. The scheme is as follows:

$$\text{slope} = \frac{f(R_1) - f(R_2)}{R_1 - R_2}$$

$$\text{obviously, slope} = \frac{f(R_1) - f(R_{\text{desired}})}{R_1 - R_{\text{new}}}$$

$$\text{therefore, } R_{\text{new}} = \frac{R_1 + f(R_{\text{desired}}) - f(R_1)}{\text{slope}}$$

If $|R_{\text{new}} - R_1| \leq 0.001R_1$, then R_{new} is indeed R_{desired} . If $|R_{\text{new}} - R_1| > 0.001R_1$, then

$$R_1 = R_2$$

$$R_2 = R_{\text{new}}$$

and another value of R is generated until the condition of $|R_{\text{new}} - R_1| \leq 0.001R_1$ is met.

This method of interpolation is valid as long as the following conditions are met:

- (1) $f(R_1) = f(R_2)$ for $R_1 = R_2$
- (2) $f(R)$ is continuous over the specified range
- (3) $f'(R)$ is continuous over the specified range.

Obviously, the closer $f(R)$ is to a straight line, the faster this scheme will work. For this reason, since the base curve overpressure plot, which is the main curve for calculating most of our quantities, has a dependence on R similar to $R^{-\text{exponent}}$, and $Q \propto R^{-2}$, a log-log plot was used; that is, instead of slope = $\frac{f(R_1) - f(R_2)}{R_1 - R_2}$, the formula slope =

$$\frac{\log f(R_1) - \log f(R_2)}{\log R_1 - \log R_2} \text{ was used.}$$

The use of this latter formula is more than just a convenience, it is a necessity when R approaches 0. At this point ($R = 0$), the necessary conditions that $f(R)$ and $f'(R)$ be continuous no

longer hold. By "flattening" the curve with the use of $\log f(R)$, the discontinuity at $R = 0$ can be much more closely approached.

APPENDIX II
FORTRAN PROGRAMS AND PRINTOUTS

A. SUBROUTINE RP 1271

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B. SUBROUTINE ARDC

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SUBROUTINE ARDC(ALTCO,PRATIO,TRATIO,ORATIO)
  ARDC
  REFERENCE
  C      R.A.KINZLER,K.S.W.CHAMPION, AND M.L.POND, THE ARDC MODEL
  C      ATMOSPHERIC, 1954; AIR FORCE SURVEYS IN GEOPHYSICS NO. 115
  C      (AFWC-TR-59-207), AIR FORCE CAMBRIDGE RES. CENTER, AUG 1959,
  C      ALTITUDE IN CENTIMETERS
  C      PRATIO= RATIO OF AMBIENT PRESSURE TO SEA LEVEL PRESSURE (1 ATM),
  C      TRATIO= RATIO OF AMBIENT TEMPERATURE TO SEA LEVEL TEMP (288.15 K),
  C      ORATIO= RATIO OF AMBIENT DENSITY TO SEA LEVEL DENSITY (.001225 G/CC)
  C
  100 ALTZ=ALTCO/100.
  ALTM=6354766.0*ALTZ/(.8356*46.0+ALTZ)
  IF(ALTM.GT.15000.0) GO TO 102
  101 TEMP=796.18+0.0045*ALTM
  PAMB=.6466178/(208.140+(208.140-0.0065*ALTM)**5.75612218)
  C
  GO TO 110
  102 IF(ALTM.GT.25000.0) GO TO 104
  103 TEMP=210.66
  PAMB=.72825524/(10.0*(0.06883253*(3.0*(ALTM-15000.0)))
  C
  GO TO 110
  104 IF(ALTM.GT.47000.0) GO TO 106
  105 TEMP=210.66+0.053*(ALTM-25000.0)
  PAMB=0.36094654/(1.11.660+3.0E-3*ALTM)/(210.66)**1.38825473
  C
  GO TO 110
  106 IF(ALTM.GT.53000.0) GO TO 108
  107 TEMP=282.66
  PAMB=0.01786667/(10.0*(0.03492662)*2.3*(ALTM-47000.0))
  C
  GO TO 110
  108 IF(ALTM.GT.70000.0) GO TO 110
  109 TEMP=252.64+0.0045*(ALTM-53000.0)
  PAMB=.040087*3/(202.66/TEMP)**7.592176)
  GO TO 110
  110 IF(ALTM.GT.90000.0) GO TO 112
  111 TEMP=165.66
  PAMB=.146195E+9*EXP(-0.0341647962*(ALTM-70000.0)/165.66)
  C
  GO TO 110
  112 IF(ALTM.GT.105000.0) GO TO 114
  113 TEMP=145.66+0.0040*(ALTM-90000.0)
  PAMB=.1551E+5*(185.66/TEMP)**8.54118
  GO TO 110
  114 IF(ALTM.GT.160000.0) GO TO 116
  115 TEMP=225.63+0.002*(ALTM-105000.0)
  PAMB=.134442E+8*(225.63/TEMP)**7.749239
  GO TO 110
  C
  116 IF(ALTM.GT.170000.0) GO TO 118
  117 TEMP=135.66+0.0035*(ALTM-160000.0)
  PAMB=.5.14015E+3*(135.66/TEMP)**3.4164704
  GO TO 110
  118 IF(ALTM.GT.200000.0) GO TO 121
  119 TEMP=145.66+0.0035*(ALTM-170000.0)
  PAMB=.6654E+2*(145.66/TEMP)**6.832958
  GO TO 110
  121 TEMP=157.66+0.0035*(ALTM-200000.0)
  PAMB=.2.0731E+2*(157.66/TEMP)**6.751369
  110 TRATIO=(PAMB/286.16
  PRATIO=(PAMB/14.696378
  DENSAM=.2365427E+6*PAMB/TEMP
  C DENSM IS IN UNITS OF SLUGS PER SQUARE INCH PER FOOT.
  ORATIO=DENSAM/.000165
  RETURN
  END

```

1. PEAK OVERPRESSURE PROGRAM

[illegible]

4:40/72 9:40 AM 22002,3 1002 COMPILER
0 MIN 20 SEC FOR COMPILE PASS
92 CARDS AT 100 CARDS PER MINUTE
1036 DIGITS DATA, 3340 DIGITS CODE.

D. PEAK OVERPRESSURE PRINTOUT

[illegible]

E. DYNAMIC PRESSURE PROGRAM

[illegible]

~~01/20/72 1113 PM 25004.5 15072 COMPILER~~
~~0 MIN 40 SEC FOR COMPILE TIME PASS~~
~~92 CARDS AT 100 CARDS PER MINUTE~~
~~1430 DIGITS DATA, 1300 DIGITS CODE.~~

F. DYNAMIC PRESSURE PRINTOUT

[illegible]

G. PARTICLE VELOCITY PRINTOUT

[illegible]

H. DENSITY RATIO PRINTOUT

[illegible]

I. RHO-U PRINTOUT

[illegible]

J. PRESSURE RATIO PROGRAM

[illegible]

K. PRESSURE RATIO PRINTOUT

28

L. SHOCK STRENGTH PRINTOUT

2	CUST	Rate
.1400E+01	.0000E+00	.2000E+00

VAL= .074E+01

[illegible]

VALUATION

[illegible]

VAL# .2368+.11

[illegible]

VAL= .1095471

[illegible]

VAL# .1075+71

AL1	AL2	AL3	AL4	AL5	AL6	AL7	AL8	AL9	AL10	AL11	AL12	AL13	AL14	AL15	AL16	AL17	AL18	AL19	AL20	AL21	AL22	AL23	AL24	AL25	AL26	AL27	AL28	AL29	AL30	AL31	AL32	AL33	AL34	AL35	AL36	AL37	AL38	AL39	AL40	AL41	AL42	AL43	AL44	AL45	AL46	AL47	AL48	AL49	AL50	AL51	AL52	AL53	AL54	AL55	AL56	AL57	AL58	AL59	AL60	AL61	AL62	AL63	AL64	AL65	AL66	AL67	AL68	AL69	AL70	AL71	AL72	AL73	AL74	AL75	AL76	AL77	AL78	AL79	AL80	AL81	AL82	AL83	AL84	AL85	AL86	AL87	AL88	AL89	AL90	AL91	AL92	AL93	AL94	AL95	AL96	AL97	AL98	AL99	AL100	AL101	AL102	AL103	AL104	AL105	AL106	AL107	AL108	AL109	AL110	AL111	AL112	AL113	AL114	AL115	AL116	AL117	AL118	AL119	AL120	AL121	AL122	AL123	AL124	AL125	AL126	AL127	AL128	AL129	AL130	AL131	AL132	AL133	AL134	AL135	AL136	AL137	AL138	AL139	AL140	AL141	AL142	AL143	AL144	AL145	AL146	AL147	AL148	AL149	AL150	AL151	AL152	AL153	AL154	AL155	AL156	AL157	AL158	AL159	AL160	AL161	AL162	AL163	AL164	AL165	AL166	AL167	AL168	AL169	AL170	AL171	AL172	AL173	AL174	AL175	AL176	AL177	AL178	AL179	AL180	AL181	AL182	AL183	AL184	AL185	AL186	AL187	AL188	AL189	AL190	AL191	AL192	AL193	AL194	AL195	AL196	AL197	AL198	AL199	AL200	AL201	AL202	AL203	AL204	AL205	AL206	AL207	AL208	AL209	AL210	AL211	AL212	AL213	AL214	AL215	AL216	AL217	AL218	AL219	AL220	AL221	AL222	AL223	AL224	AL225	AL226	AL227	AL228	AL229	AL230	AL231	AL232	AL233	AL234	AL235	AL236	AL237	AL238	AL239	AL240	AL241	AL242	AL243	AL244	AL245	AL246	AL247	AL248	AL249	AL250	AL251	AL252	AL253	AL254	AL255	AL256	AL257	AL258	AL259	AL260	AL261	AL262	AL263	AL264	AL265	AL266	AL267	AL268	AL269	AL270	AL271	AL272	AL273	AL274	AL275	AL276	AL277	AL278	AL279	AL280	AL281	AL282	AL283	AL284	AL285	AL286	AL287	AL288	AL289	AL290	AL291	AL292	AL293	AL294	AL295	AL296	AL297	AL298	AL299	AL300	AL301	AL302	AL303	AL304	AL305	AL306	AL307	AL308	AL309	AL310	AL311	AL312	AL313	AL314	AL315	AL316	AL317	AL318	AL319	AL320	AL321	AL322	AL323	AL324	AL325	AL326	AL327	AL328	AL329	AL330	AL331	AL332	AL333	AL334	AL335	AL336	AL337	AL338	AL339	AL340	AL341	AL342	AL343	AL344	AL345	AL346	AL347	AL348	AL349	AL350	AL351	AL352	AL353	AL354	AL355	AL356	AL357	AL358	AL359	AL360	AL361	AL362	AL363	AL364	AL365	AL366	AL367	AL368	AL369	AL370	AL371	AL372	AL373	AL374	AL375	AL376	AL377	AL378	AL379	AL380	AL381	AL382	AL383	AL384	AL385	AL386	AL387	AL388	AL389	AL390	AL391	AL392	AL393	AL394	AL395	AL396	AL397	AL398	AL399	AL400	AL401	AL402	AL403	AL404	AL405	AL406	AL407	AL408	AL409	AL410	AL411	AL412	AL413	AL414	AL415	AL416	AL417	AL418	AL419	AL420	AL421	AL422	AL423	AL424	AL425	AL426	AL427	AL428	AL429	AL430	AL431	AL432	AL433	AL434	AL435	AL436	AL437	AL438	AL439	AL440	AL441	AL442	AL443	AL444	AL445	AL446	AL447	AL448	AL449	AL450	AL451	AL452	AL453	AL454	AL455	AL456	AL457	AL458	AL459	AL460	AL461	AL462	AL463	AL464	AL465	AL466</
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VALUATION

[illegible]

M. DENSITY PRINTOUT

N	COST	RKFI	Q	GYP	NYMP	PARVEL	DEASTY	DEARAT	RMDU	OTWER
VAL=	300E+00	4	0	0	0	0	0	0	0	0
ALT	4	RKFI	0	GYP	NYMP	PARVEL	DEASTY	DEARAT	RMDU	OTWER
.000E+00	.100E+01	.250E+00	.500E+03	.145E+03	.211E+03	.255E+04	.302E+00	.392E+01	.740E+03	.300E+00
.305E+01	.100E+01	.160E+00	.119E+04	.441E+03	.931E+03	.542E+04	.300E+00	.531E+01	.163E+04	.300E+00
FAILED TO CONVERGE.										
.014E+01	.100E+01	.000E+00	.1.9E+04	.000E+00	.000E+00	.000E+00	.28E+01	.100E+01	.000E+00	.24E+01
.122E+02	.100E+01	.000E+00	.119E+04	.000E+00	.000E+00	.000E+00	.18E+01	.100E+01	.000E+00	.149E+01
.157E+02	.100E+01	.000E+00	.119E+04	.000E+00	.000E+00	.000E+00	.11E+01	.100E+01	.000E+00	.116E+01
.182E+02	.100E+01	.000E+00	.119E+04	.000E+00	.000E+00	.000E+00	.73E+02	.100E+01	.000E+00	.734E+02
.217E+02	.100E+01	.000E+00	.119E+04	.000E+00	.000E+00	.000E+00	.45E+02	.100E+01	.000E+00	.453E+02
.243E+02	.100E+01	.000E+00	.119E+04	.000E+00	.000E+00	.000E+00	.78E+02	.100E+01	.000E+00	.783E+02
.274E+02	.100E+01	.000E+00	.119E+04	.000E+00	.000E+00	.000E+00	.17E+02	.100E+01	.000E+00	.170E+02
.305E+02	.100E+01	.000E+00	.119E+04	.000E+00	.000E+00	.000E+00	.10E+02	.100E+01	.000E+00	.103E+02
VAL=	.200E+00	4	0	0	0	0	0	0	0	0
ALT	4	RKFI	0	GYP	NYMP	PARVEL	DEASTY	DEARAT	RMDU	OTWER
.000E+00	.100E+01	.391E+00	.20E+03	.490E+02	.396E+02	.135E+04	.200E+00	.261E+01	.271E+03	.200E+00
.305E+01	.100E+01	.314E+00	.313E+03	.712E+02	.930E+02	.207E+04	.200E+00	.354E+01	.415E+03	.300E+00
.610E+01	.100E+01	.229E+00	.583E+03	.166E+03	.329E+03	.390E+04	.200E+00	.690E+01	.740E+03	.200E+00
FAILED TO CONVERGE.										
.122E+02	.100E+01	.000E+00	.53E+03	.000E+00	.000E+00	.000E+00	.14E+01	.100E+01	.000E+00	.149E+01
.157E+02	.100E+01	.000E+00	.58E+03	.000E+00	.000E+00	.000E+00	.11E+01	.100E+01	.000E+00	.116E+01
.182E+02	.100E+01	.000E+00	.58E+03	.000E+00	.000E+00	.000E+00	.73E+02	.100E+01	.000E+00	.734E+02
.217E+02	.100E+01	.000E+00	.58E+03	.000E+00	.000E+00	.000E+00	.45E+02	.100E+01	.000E+00	.453E+02
.243E+02	.100E+01	.000E+00	.58E+03	.000E+00	.000E+00	.000E+00	.78E+02	.100E+01	.000E+00	.783E+02
.274E+02	.100E+01	.000E+00	.58E+03	.000E+00	.000E+00	.000E+00	.17E+02	.100E+01	.000E+00	.170E+02
.305E+02	.100E+01	.000E+00	.58E+03	.000E+00	.000E+00	.000E+00	.10E+02	.100E+01	.000E+00	.103E+02
VAL=	.150E+00	4	0	0	0	0	0	0	0	0
ALT	4	RKFI	0	GYP	NYMP	PARVEL	DEASTY	DEARAT	RMDU	OTWER
.000E+00	.100E+01	.239E+00	.109E+03	.245E+02	.183E+02	.452E+03	.153E+00	.13E+01	.120E+03	.150E+00
.305E+01	.100E+01	.430E+00	.218E+03	.350E+02	.290E+02	.134E+04	.150E+00	.264E+01	.270E+03	.150E+00
.610E+01	.100E+01	.345E+00	.280E+03	.565E+02	.470E+02	.212E+04	.150E+00	.384E+01	.319E+03	.150E+00
.122E+02	.100E+01	.221E+00	.577E+03	.149E+03	.357E+03	.470E+04	.150E+00	.523E+01	.704E+03	.150E+00
FAILED TO CONVERGE.										
.122E+02	.100E+01	.000E+00	.577E+03	.000E+00	.					

N. THERMAL FLUX PROGRAM

THERMAL FLUX PROGRAM

[illegible]

01/11/72 12133 PM 45MB.5 13172 COMPILER
C N14 50 SFC FOR COMPILATION PASS
45 CAMDS AT 001 CAMDS PER MINUTE
1987 BYGITS DATA, 3054 EIGHTS CORR.

O. THERMAL FLUX PRINTOUT

[illegible]