(4)

86-15

DASIAC-TN-86-15

HANDBOOK OF HE EXPLOSION EFFECTS

J. Petes
Kaman Tempo
Alexandria Office
Huntington Building
2560 Huntington Avenue
Alexandria, VA 22303-1410

11 April 1986

Technical Report

CONTRACT No. DNA 001-82-C-0274

Approved for public release;
distribution is unlimited.

THIS WORK WAS SPONSORED BY THE DEFENSE NUCLEAR AGENCY
UNDER RDT&E RMSS CODE B337084466 P99QMXDC00001 H2590D.

Prepared for
Director
DEFENSE NUCLEAR AGENCY
Washington, DC 20305-1000

DASIAC-TN-86-15

HANDBOOK OF HE EXPLOSION EFFECTS

J. Petes
Kaman Tempo
Alexandria Office
Huntington Building
2560 Huntington Avenue
Alexandria, VA 22303-1410

11 April 1986

Technical Report

CONTRACT No. DNA 001-82-C-0274

Approved for public release;
distribution is unlimited.

THIS WORK WAS SPONSORED BY THE DEFENSE NUCLEAR AGENCY
UNDER RDT&E RMSS CODE B337084466 P99QMXDC00001 H2590D.

Prepared for
Director
DEFENSE NUCLEAR AGENCY
Washington, DC 20305-1000

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

AD A200874

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY N/A since Unclassified	3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
2b DECLASSIFICATION/DOWNGRADING SCHEDULE N/A since Unclassified	
4 PERFORMING ORGANIZATION REPORT NUMBER(S) DASIAC TN 86-15	5 MONITORING ORGANIZATION REPORT NUMBER(S) DASIAC TN 86-15
6a NAME OF PERFORMING ORGANIZATION Kaman Tempo Alexandria Office 6b OFFICE SYMBOL (If applicable)	7a NAME OF MONITORING ORGANIZATION Director Defense Nuclear Agency
6c ADDRESS (City, State, and ZIP Code) Huntington Building 2560 Huntington Avenue Alexandria, VA 22303-1410	7b ADDRESS (City, State, and ZIP Code) Washington, DC 20305-1000
8a NAME OF FUNDING/SPONSORING ORGANIZATION 8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DNA 001-82-C-0274
8c ADDRESS (City, State, and ZIP Code)	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO: 62715H; PROJECT NO: P99QMXD; TASK NO: C; WORK UNIT ACCESSION NO: DH007216

11 TITLE (Include Security Classification)
HANDBOOK OF P. EXPLOSION EFFECTS

12 PERSONAL AUTHOR(S)
Petes, J.

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Technical	FROM 840411 TO 860411	860411	

16 SUPPLEMENTARY NOTATION
This work was sponsored by the Defense Nuclear Agency under RDT&E RMSS Code B337084466 P99QMXD00601 H25900.

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB GROUP	Explosion Effects, Explosions In Air, Handbook, TNT, Explosions, Airblast, ~~ANFO Explosions~~, Craters, Free Field
19	6		

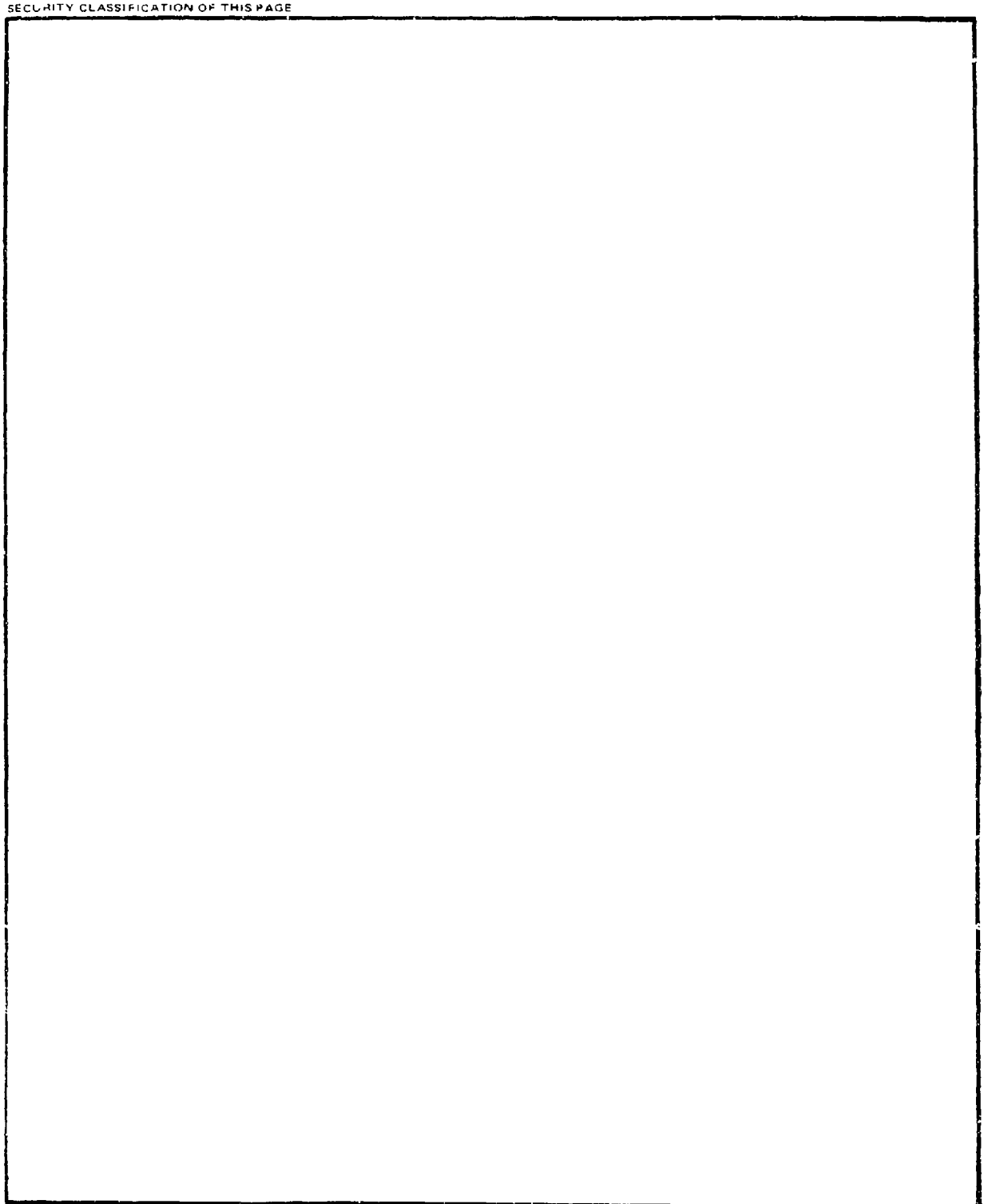
19 ABSTRACT (Continue on reverse if necessary and identify by block number)

This Handbook is intended for use by program managers, participants in high-explosive field tests, and others requiring a ready reference to airblast and crater effects of conventional explosives. To facilitate this aim, the Handbook is in pocket- and desk-sized forms. By the use of overlays, effects parameters are available for charges 1 lb. to 10 million lbs. The overlay technique obviates the need to resort to normal scaling procedures, pencil and paper calculations, or calculators. Keywords

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT	21 ABSTRACT SECURITY CLASSIFICATION
☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS	UNCLASSIFIED
22a NAME OF RESPONSIBLE INDIVIDUAL Sandra E. Young	22b TELEPHONE (Include Area Code) (202)325-7042
	22c OFFICE SYMBOL DNA/CSTI

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED



Preface

This Handbook of HE Explosion Effects is intended for use by blast experts, test planners, safety engineers, accident investigators, administrators, and other interested persons who may, at times, require a quick and reliable answer as to the effects of explosions from conventional high explosives (HE) and propellants. Overlays are used to determine major effects for charges weighing from 10^0 to 10^7 pounds without recourse to usual scaling procedures. However, most of the information is provided in a form suitable for scaling if so desired.

The data presented in this handbook are based almost completely on experimental results rather than on hydrocode calculations. The values read off of the graphs are with ±10 percent of those that would be obtained from the original source material referenced and annotated in Section 4.

The effects from only two explosives are covered in some detail: TNT, because it is common practice to relate and compare explosions from many sources to TNT explosions; and ANFO, because it has wide use in military tests where it is required to simulate nuclear weapon-proportioned blast and shock. The effects from several other explosives and propellants can be determined by use of the equivalent weight values given on page 23. (The ANFO data are not applicable to charges weighing less than about 500 pounds.)

The data given in this handbook pertain to explosions in a standard sea-level atmosphere.

Most of the information contained in this manual has been derived from the references cited in Section 4; only page 22 (on craters) introduces new information.

The overlay presentation was designed by Nancy Parnell who made the necessary calculations and original plots. The final graphic design was developed by Dennis Paulazzo and Bonnie Krueger.

J. Petes

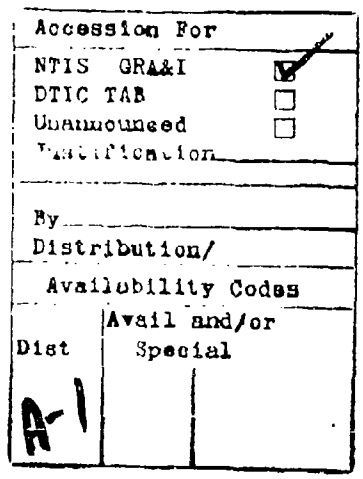


Table of Contents

	Page
Preface	iii
How To Use The Manual	1
1 Airblast	
Free-Air TNT Spheres (Overpressure vs Distance)	2
Surface TNT Spheres (Overpressure vs Distance)	3
TNT Spheres/Intermediate-Pressure (Height of Burst vs Ground Ranges)	4
TNT Spheres/Low-Pressure (Height of Burst vs Ground Ranges)	5
Ideal Blast Characteristics at Shock Front	6
Effects of Charge Geometry for Surface TNT Charges (Overpressure vs Distance)	7
TNT Hemispheres (Overpressure vs Distance)	8
TNT Hemispheres (Arrival Time vs Distance)	9
TNT Hemispheres (Positive Duration vs Distance)	10
TNT Hemispheres (Positive Impulse vs Distance)	11
Free-Air TNT Pressure Ratio (Cylinder/Sphere)	12
Surface TNT Pressure Ratio (Cylinder/Sphere)	13
ANFO Domed Cylinders (L/D = 0.75) (Overpressure vs Distance)	14
ANFO Domed Cylinders (L/D = 0.75) (Arrival Time vs Distance)	15
ANFO Domed Cylinders (L/D = 0.75) (Positive Duration vs Distance)	16
ANFO Domed Cylinders (L/D = 0.75) (Positive Impulse vs Distance)	17
ANFO Domed Cylinders (L/D = 0.75) (Positive Dynamic Pressure vs Distance)	18
ANFO Domed Cylinders (L/D = 0.75) (Positive Dynamic Pressure Impulse vs Distance)	19
2 Craters	
TNT Spheres (Apparent Crater Radius vs Depth of Burst)	20
TNT Spheres (Apparent Crater Depth vs Depth of Burst)	21
Multiplying Factors for Charges of Different Geometries	22
3 Miscellaneous	
Equivalent Weights for Peak Pressure	23
Scaling Procedures	24

Table of Contents

		Page
	Cube Root of Numbers	25
	Meter/Feet Conversion	26
	psi/kPa Conversion	27
	Airblast Criteria for Personnel Standing in the Open (Part 1)	28
	Airblast Criteria for Personnel Standing in the Open (Part 2)	29
4	Annotated Sources of Information	30

How To Use The Manual

Most of the effects information is presented in the form of plots for 1-pound charges, fired in a standard sea-level atmosphere. The overlays permit reading effects values for the parameters of interest for charges weighing from 10^0 to 10^7 pounds.

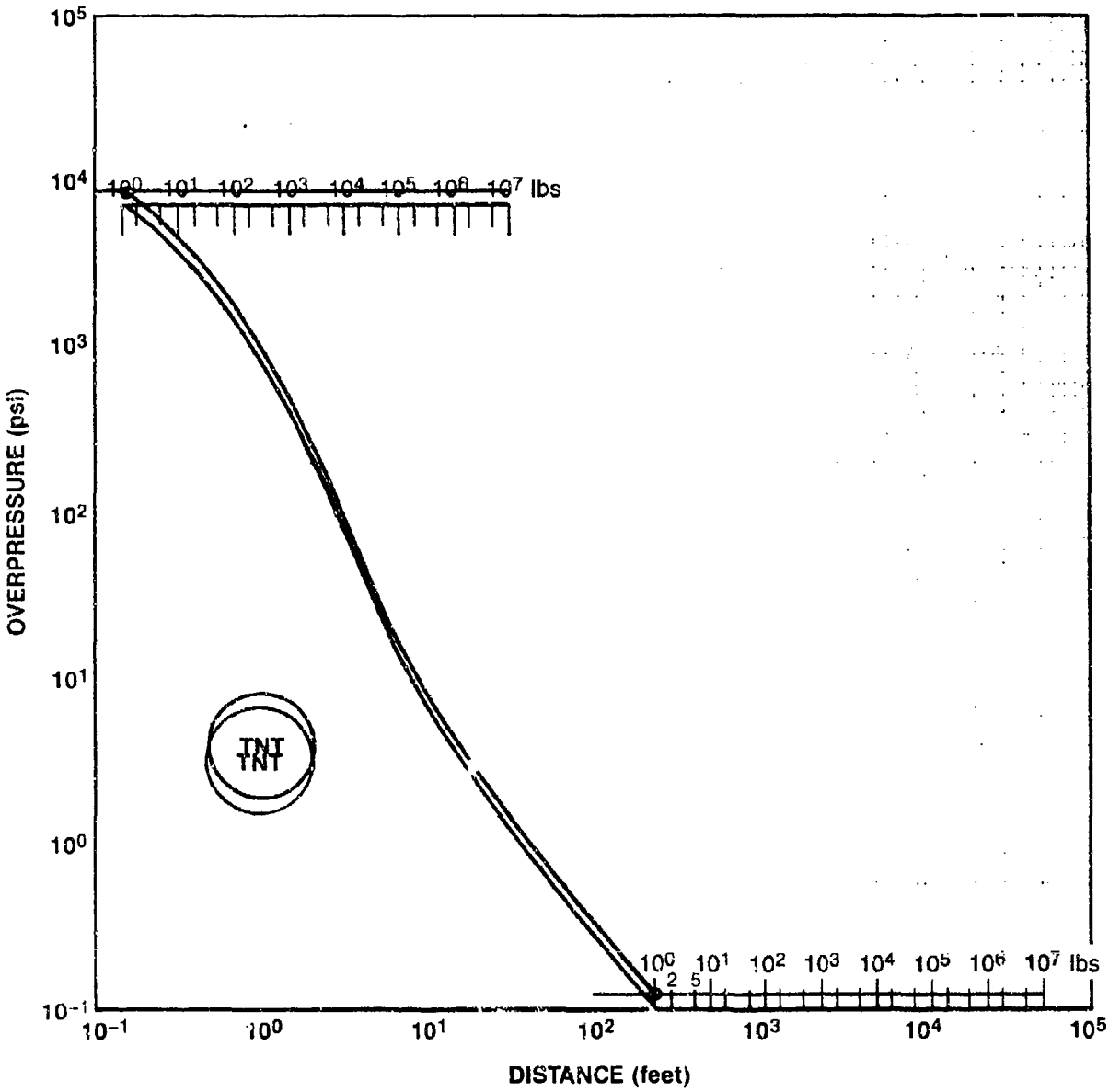
For overlays on pages 4, 5, 20, and 21, line the bottom and left axes of the overlay with the charge weight scale of interest and read the parameters directly. In a similar fashion with the remaining overlays, place the overlay on the graph, aligning the targets with the charge weight of interest on both the bottom and top weight scales and read the parameters directly.

A test example illustrating the use of the overlays is included on many of the graphs.

An alternative to using the overlays would be to use a scaling procedure to determine the required data since all plots are based on 1-pound charges. See page 24 for simplified scaling procedures.

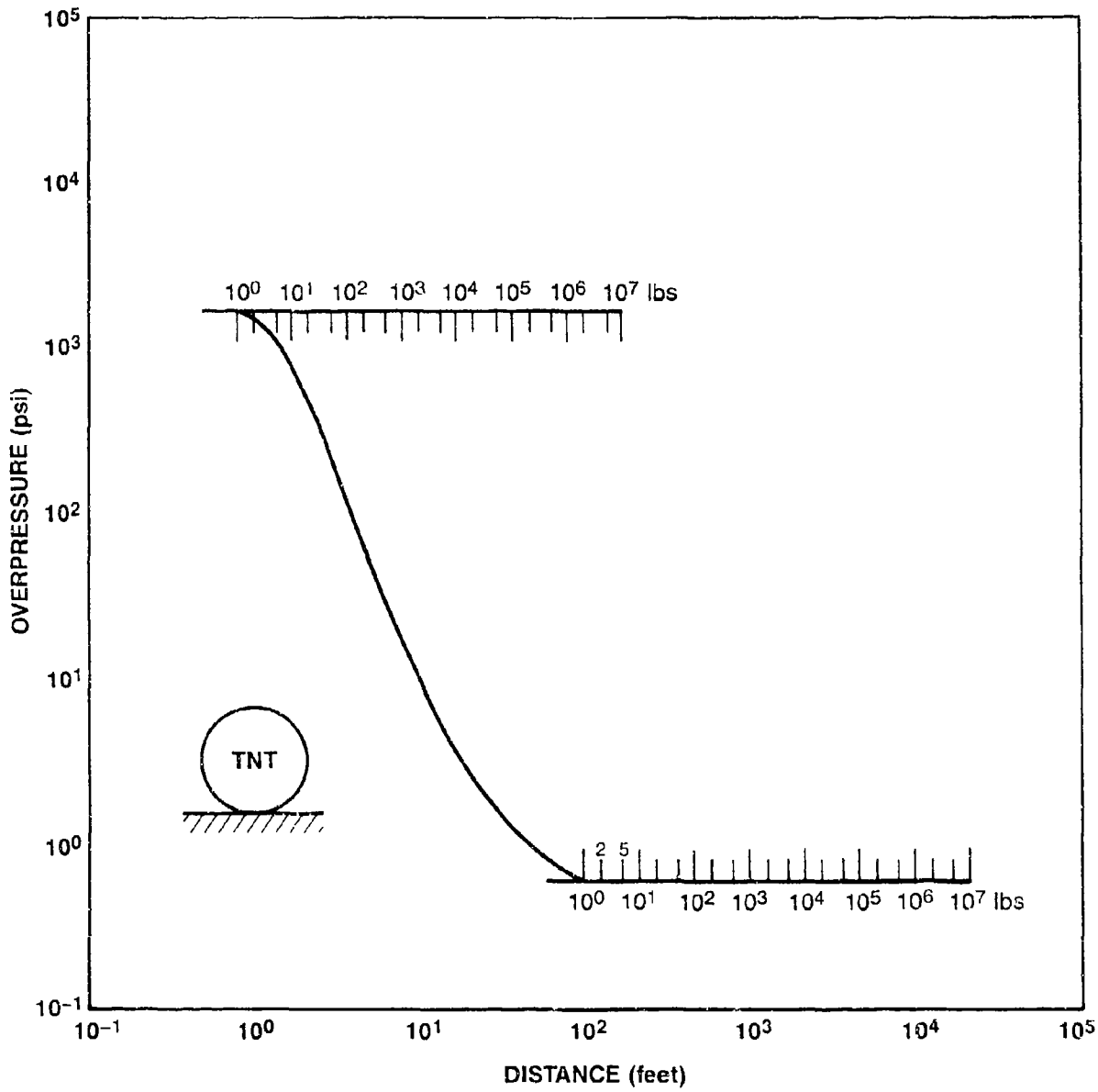
Section 1
AIRBLAST

Free Air TNT Spheres
Overpressure vs Distance



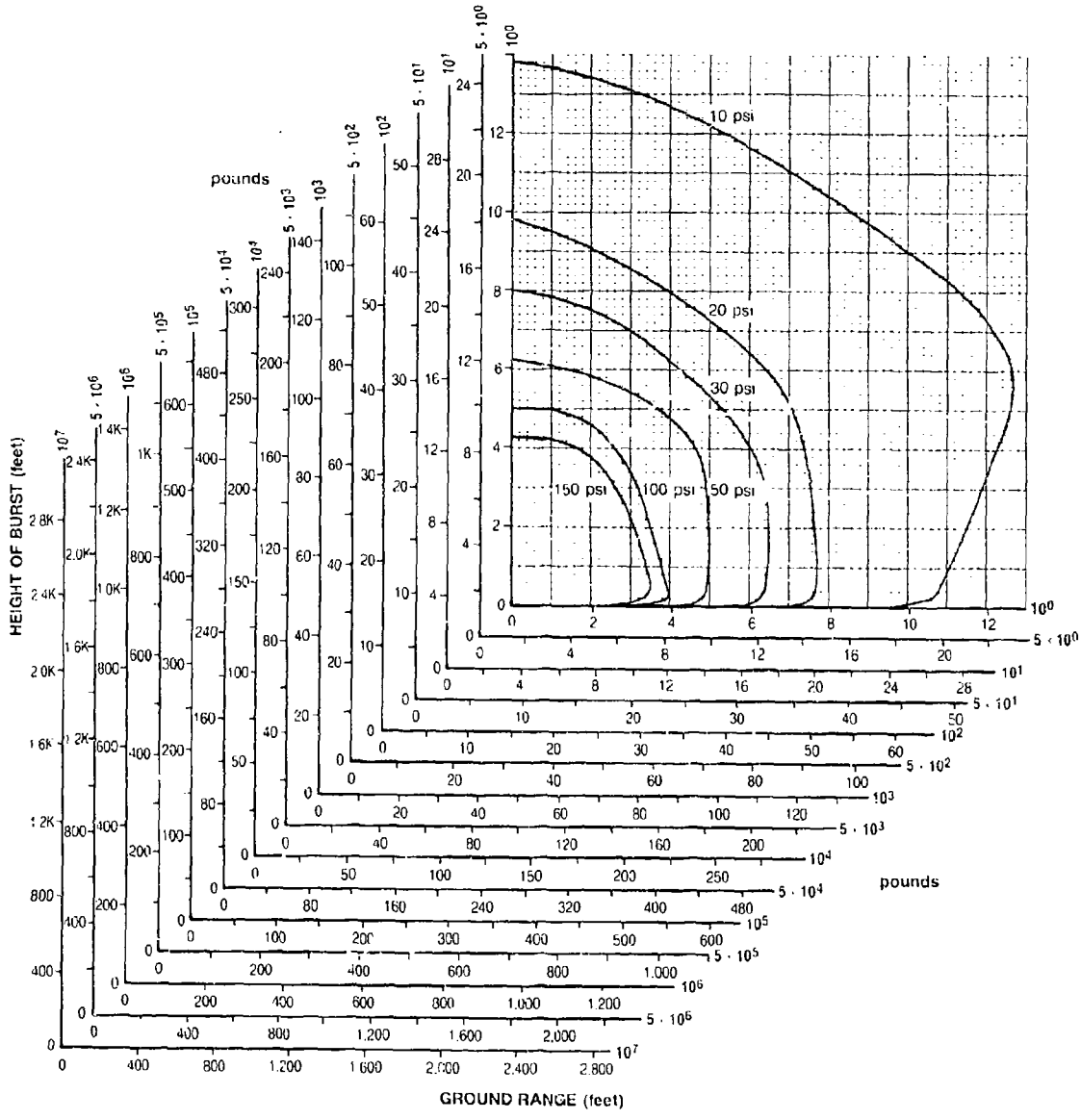
Example: For 20,000 lbs, at 1,000 feet, pressure = 1 psi

Surface TNT Spheres
Overpressure vs Distance



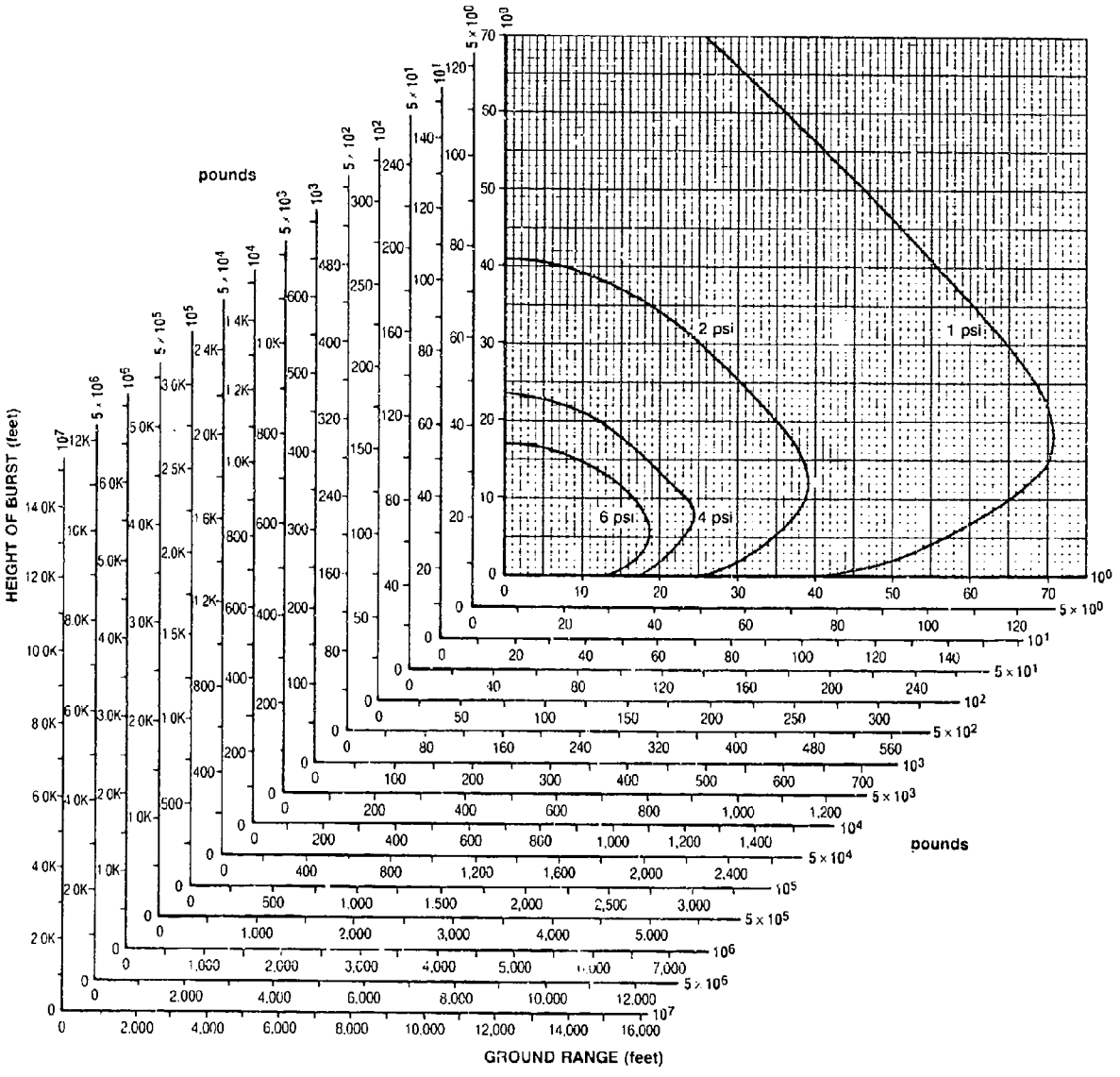
Example: For 5,000 lbs, 22 psi is at 125 feet

TNT Spheres/Intermediate-Pressure
Height of Burst vs Ground Ranges



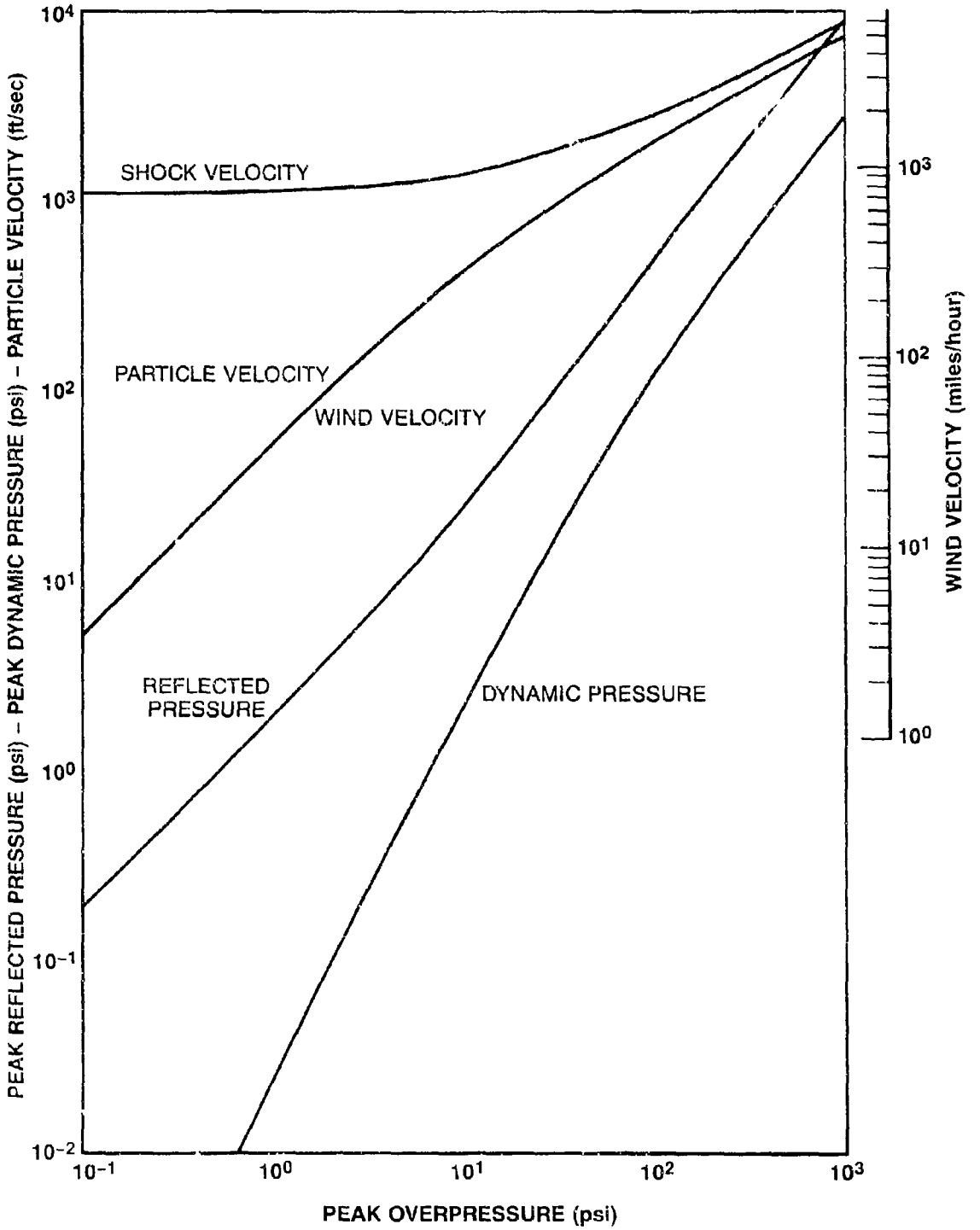
Example: For 1,000 lbs at an HOB = 50 feet, 20 psi is at 68 feet

TNT Spheres/Low-Pressure
Height of Burst vs Ground Ranges

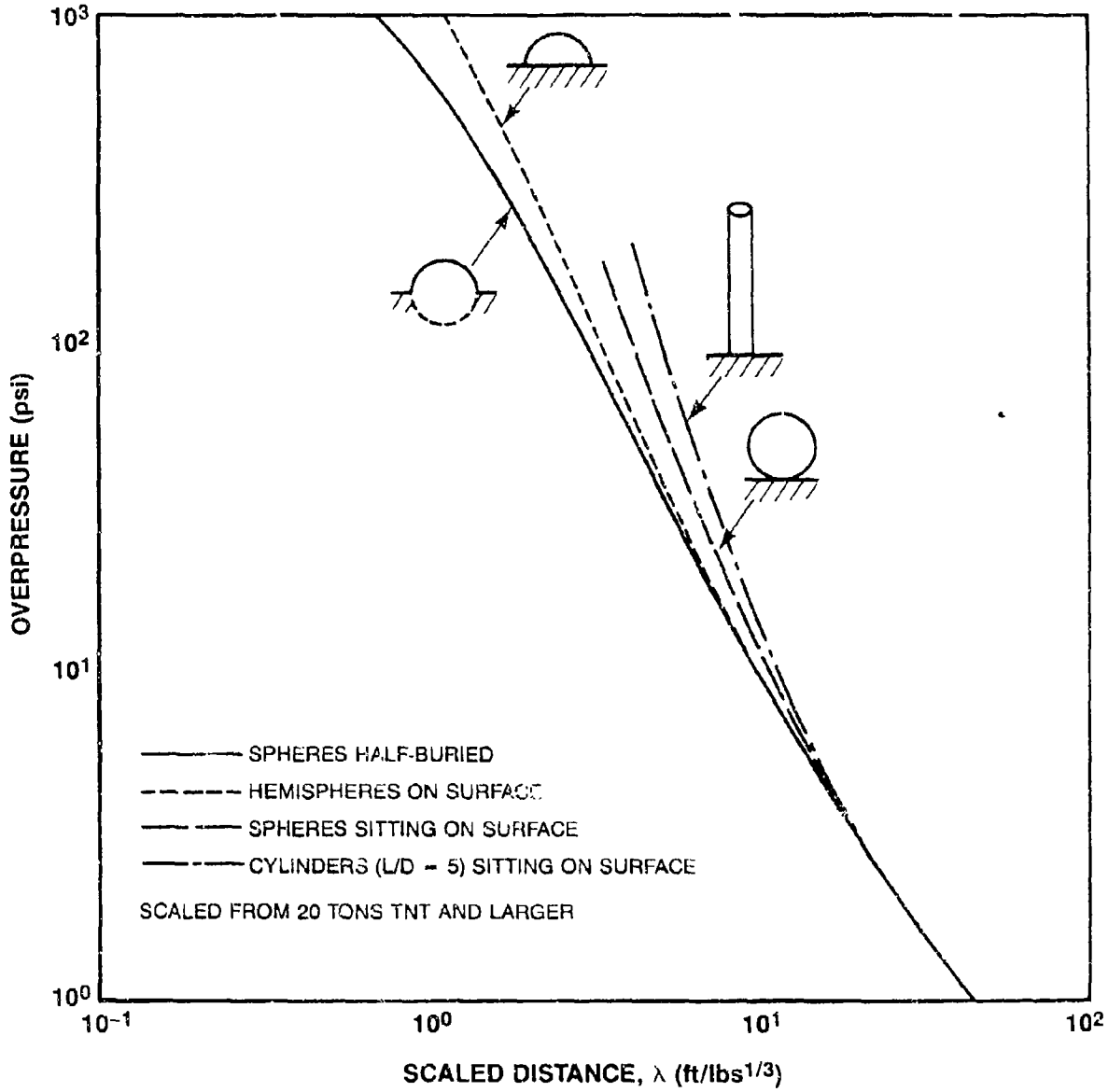


Example: For 100,000 lbs, at an HOB = 2,000 feet, 1 psi is at 2,450 feet

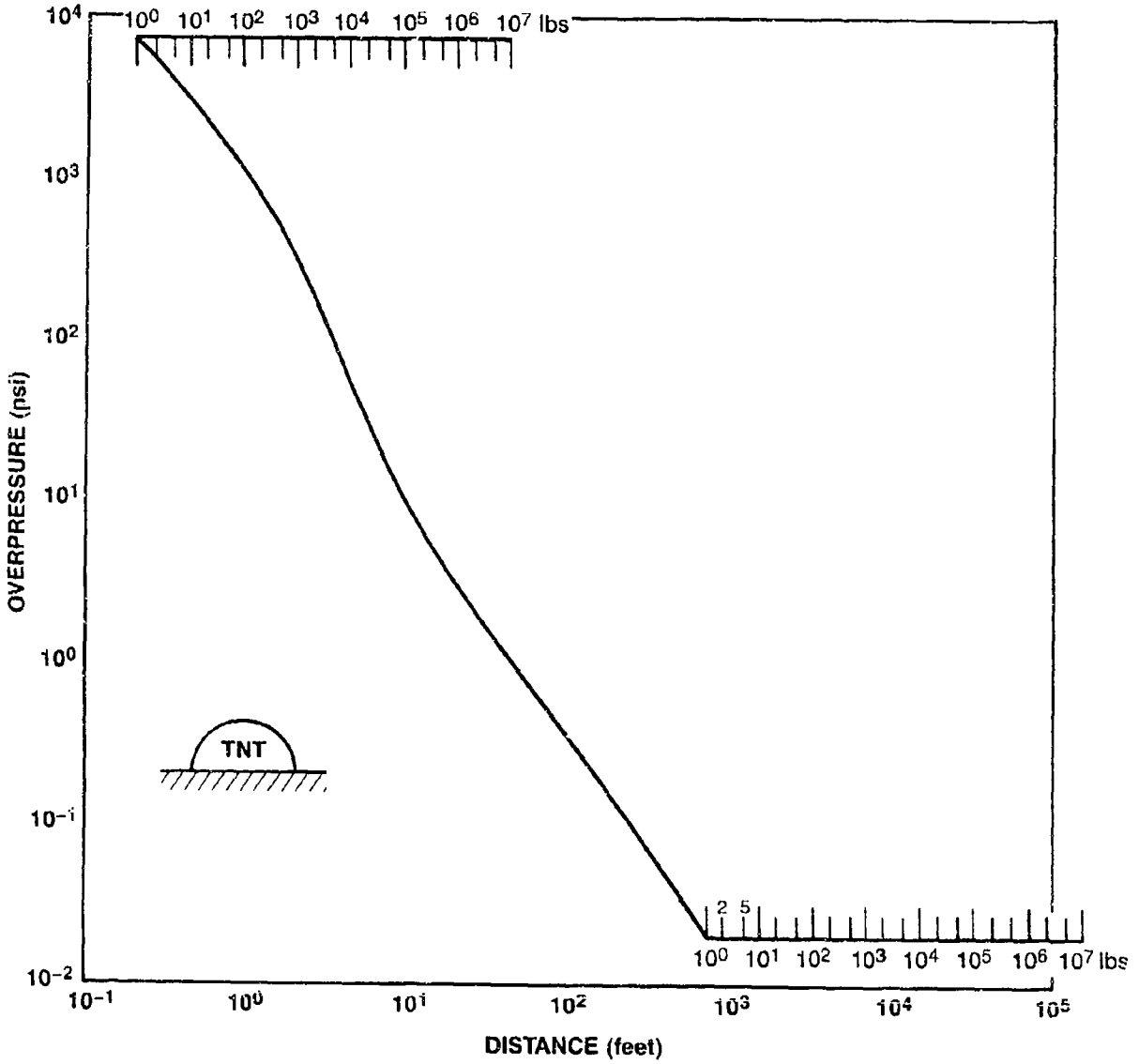
Ideal Blast Characteristics at Shock Front



Effects of Charge Geometry for Surface TNT Charges
(Overpressure vs Distance)

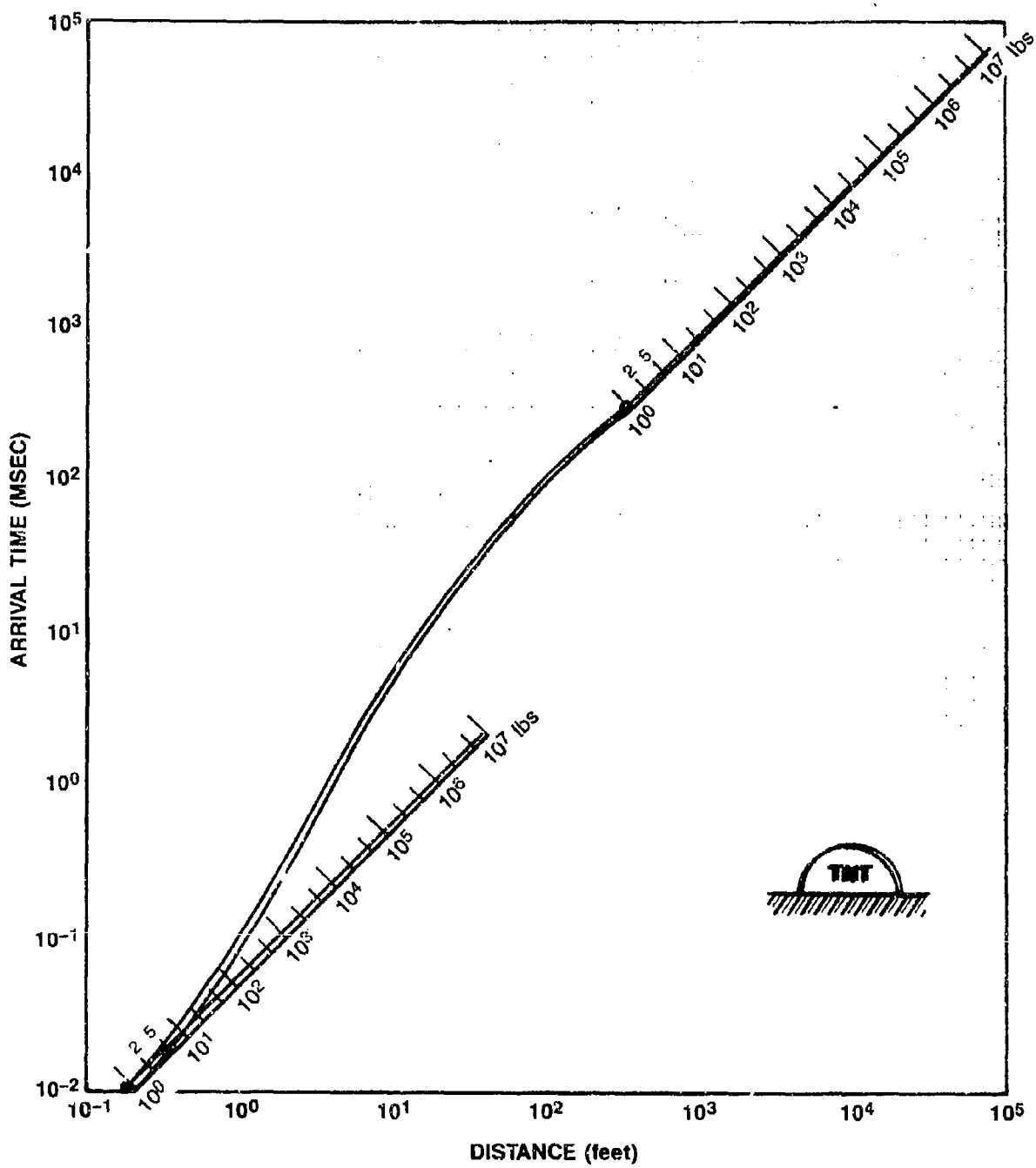


TNT Hemispheres
Overpressure vs Distance



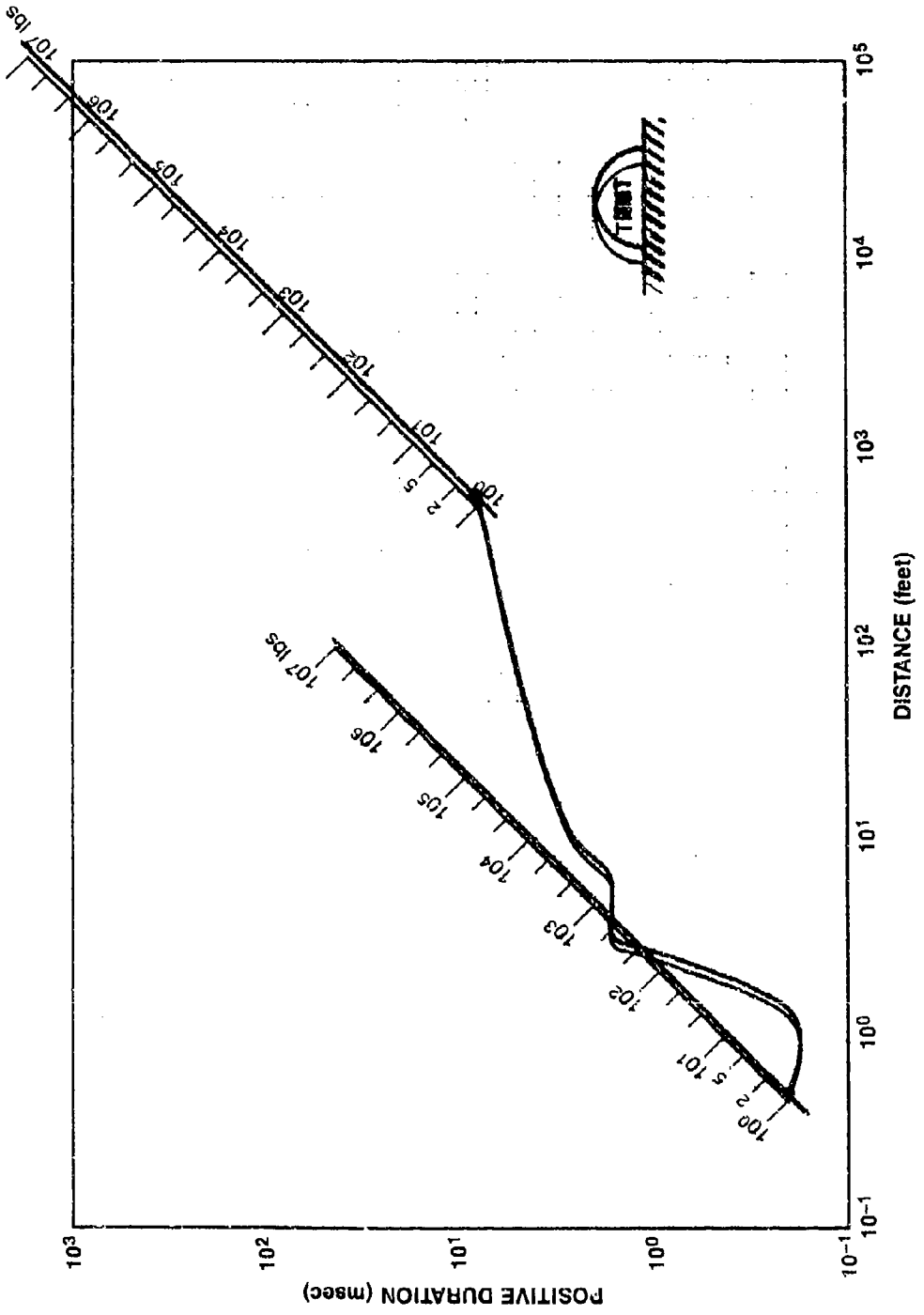
Example: For 5,000 lbs, 22 psi is at 110 feet

TNT Hemispheres
Arrival Time vs Distance



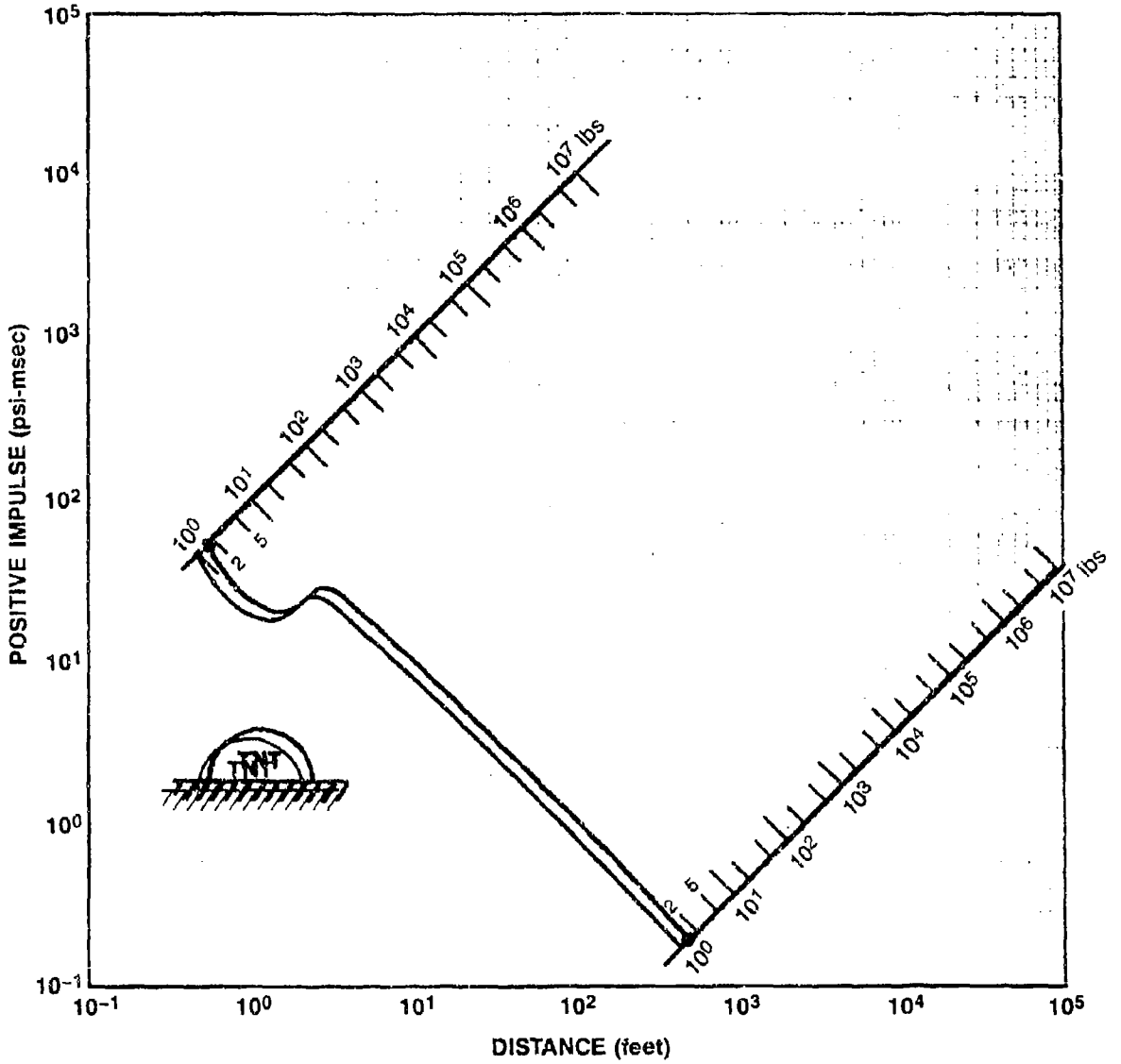
Example: For 5,000 lbs, time of arrival at 110 feet is 35 msec

TNT Hemispheres
Positive Duration vs Distance



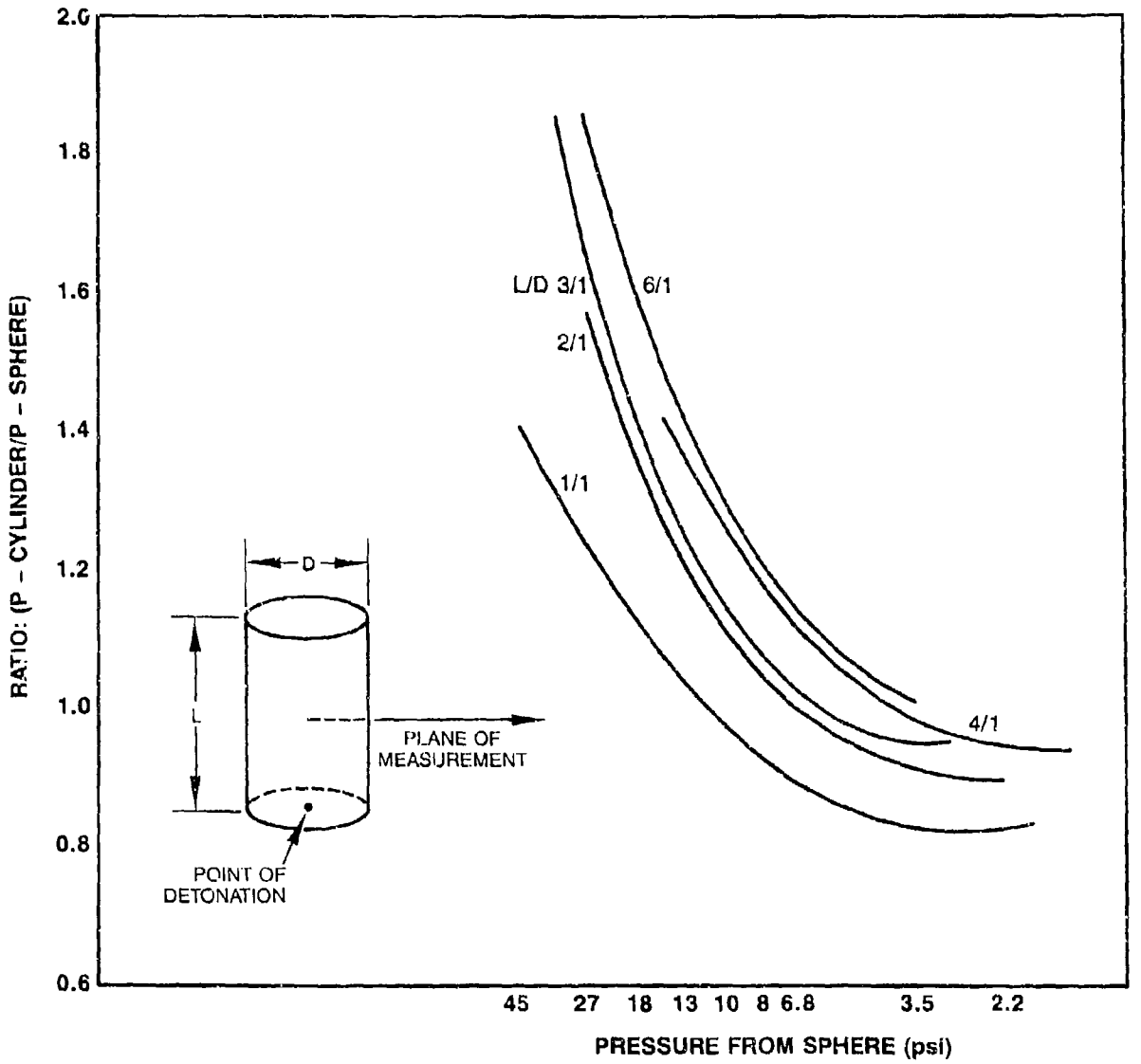
Example: For 5,000 lbs, positive duration at 110 feet is 29 msec

TNT Hemispheres
Positive Impulse vs Distance



Example: For 5,000 lbs, positive phase impulse at 110 feet is 210 psi-msec

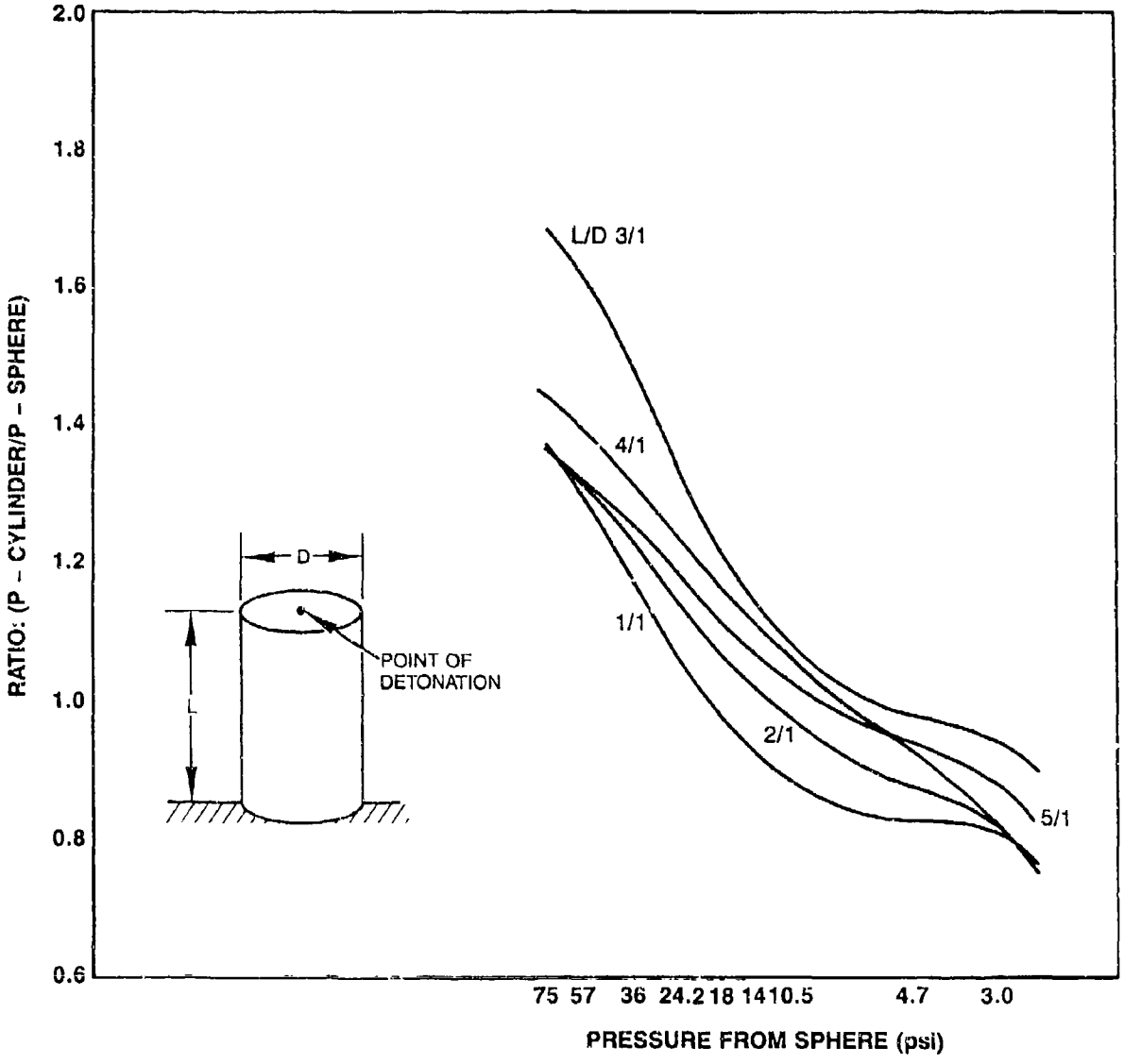
Free-Air TNT Pressure Ratio
Cylinder/Sphere



Example: What is the pressure 90 feet away from a 5,000-pound pentolite cylinder with an L/D = 2/1 detonated in free air?

1. From page 23: pentolite equivalent weight = 1.17; therefore, 5,000 pounds pentolite = 5,850 pounds TNT.
2. From page 2 overlay, at 90 feet from a 5,850-pound TNT sphere, the overpressure = 27 psi.
3. From page 12, for 27 psi from a sphere, $P_c/P_s = 1.58$ for an L/D = 2/1. Therefore, $P_c = 1.58 \times 27 = 42.7$ psi.

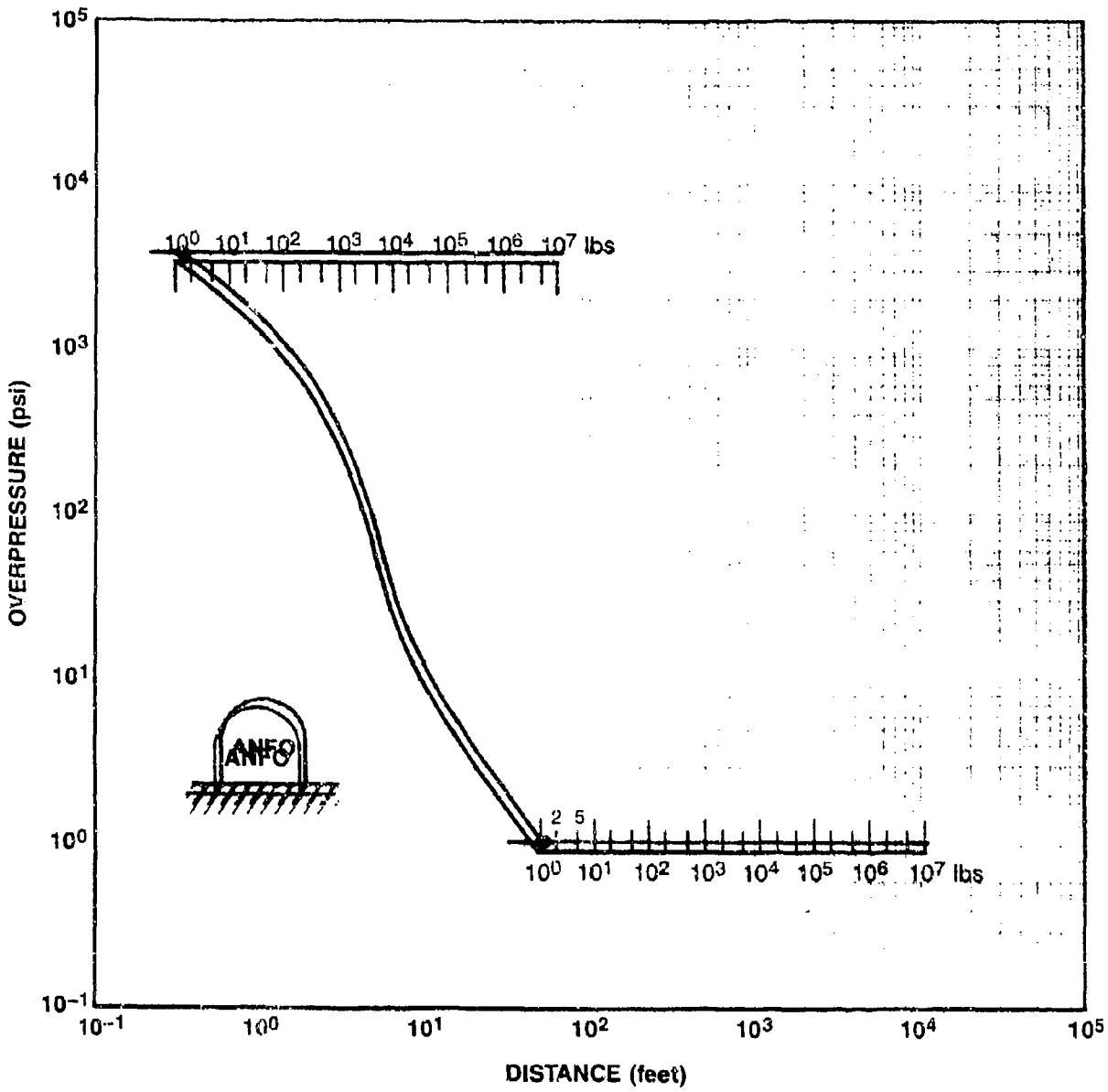
Surface TNT Pressure Ratio
Cylinder/Sphere



Example: What is the pressure 30 feet from an L/D = 3/1 TNT cylinder weighing 216 pounds?

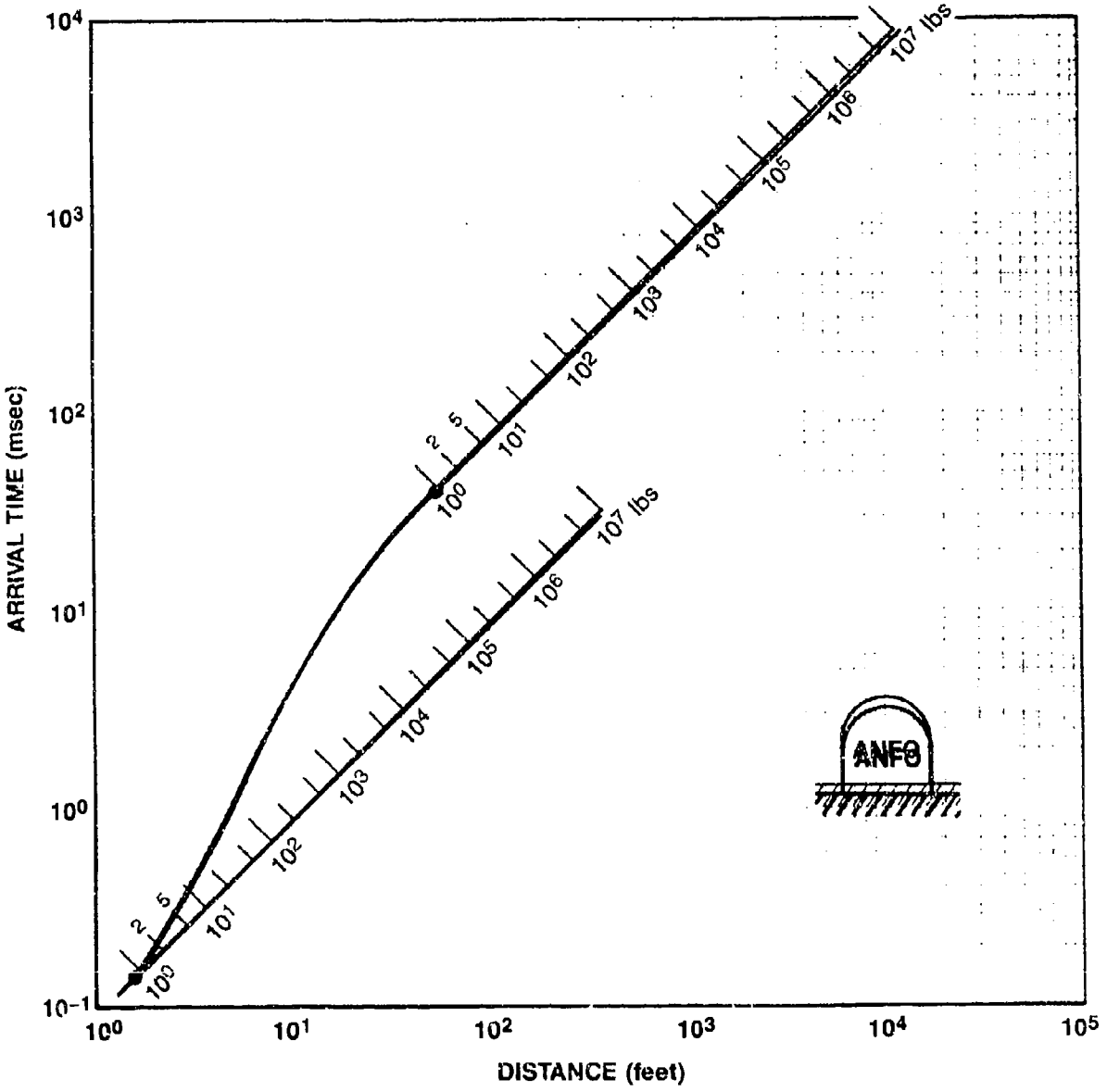
1. From page 3 overlay, at 30 feet from a 216-pound TNT sphere tangent to the surface, the overpressure = 57 psi.
2. From page 13, for 57 psi from a sphere, $P_c/P_s = 1.62$ for an L/D = 3/1. Therefore, $P_c = 1.62 \times 57 = 92.3$ psi.

ANFO Domed Cylinders (L/D = 0.75)
Overpressure vs Distance



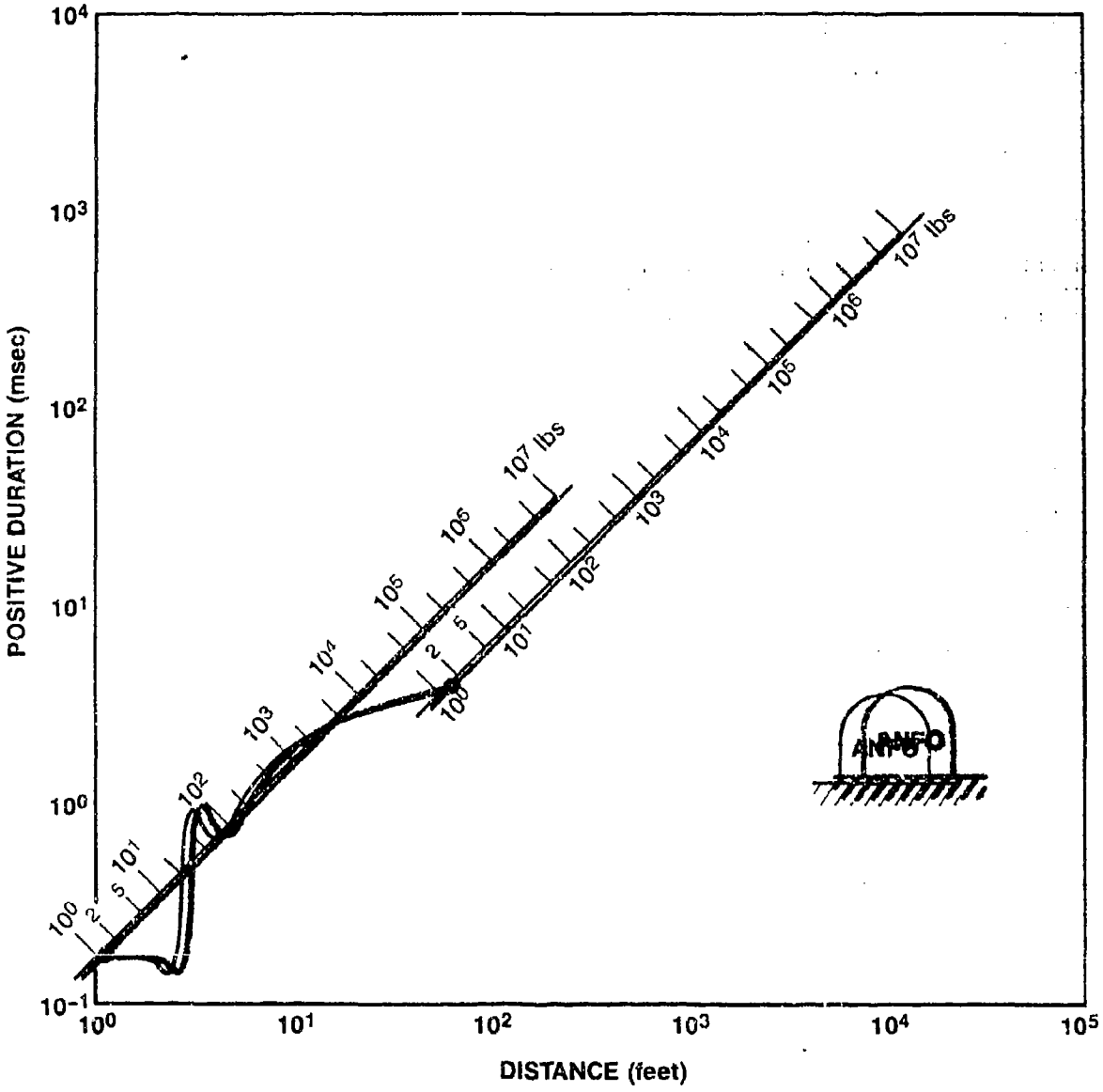
Example: For 100,000 lbs, at 200 feet, pressure = 110 psi

ANFO Domed Cylinders (L/D = 0.75)
Arrival Time vs Distance



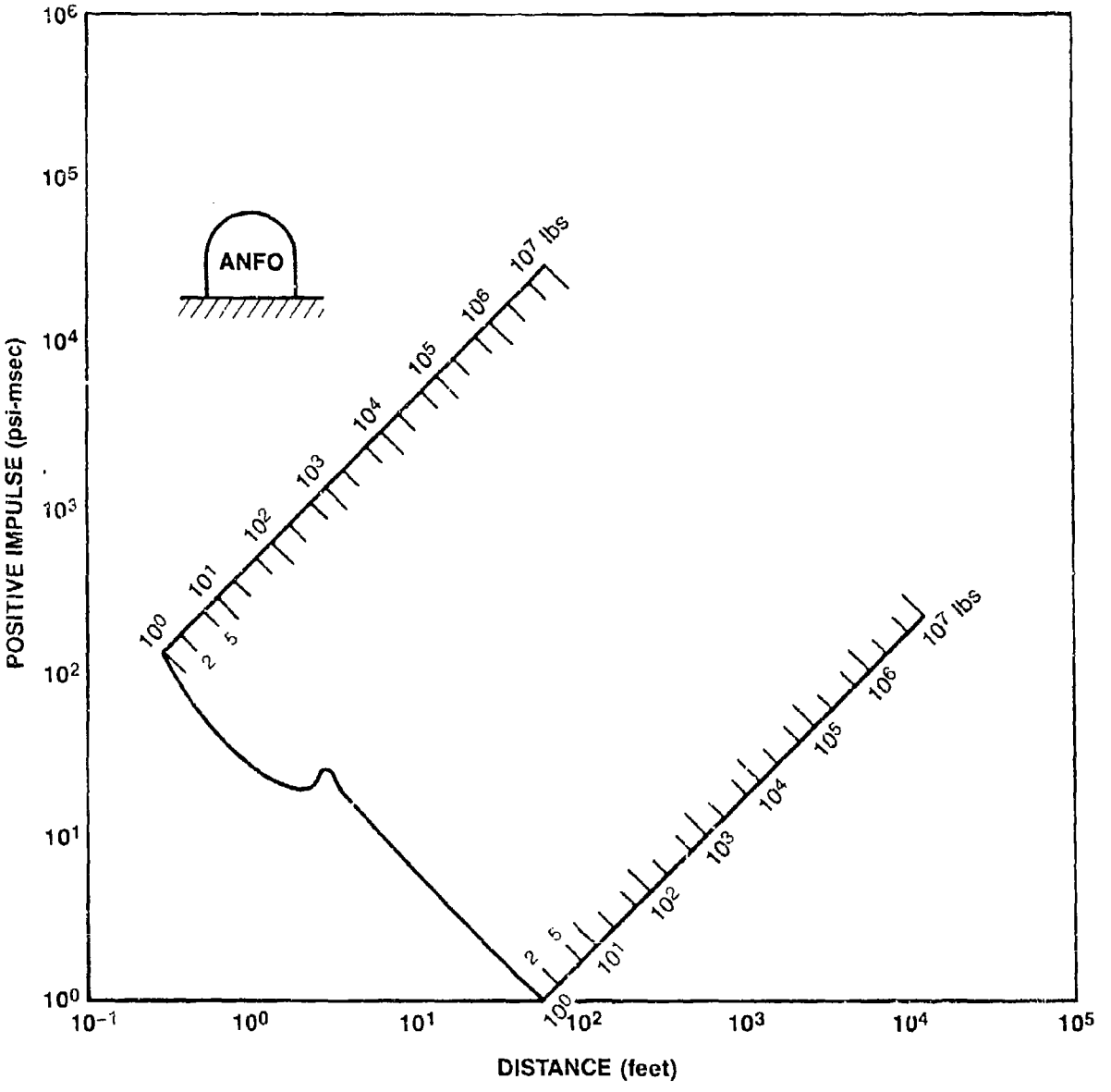
Example: For 100,000 lbs, at 200 feet, arrival time = 34 msec

ANFO Domed Cylinders (L/D = 0.75)
Positive Duration vs Distance



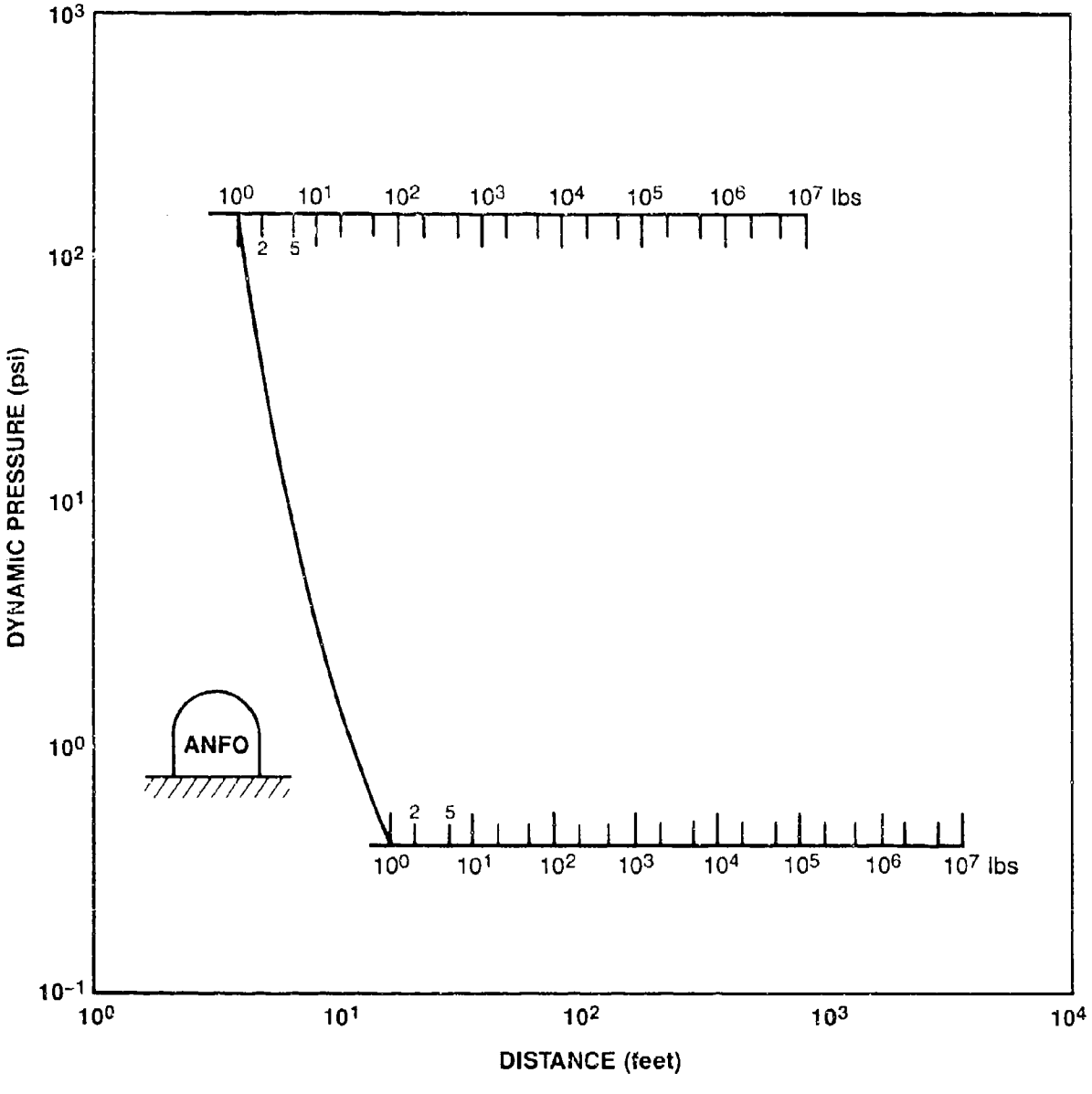
Example: For 100,000 lbs, at 200 feet, positive duration is 32 msec

ANFO Domed Cylinders (L/D = 0.75)
Positive Impulse vs Distance



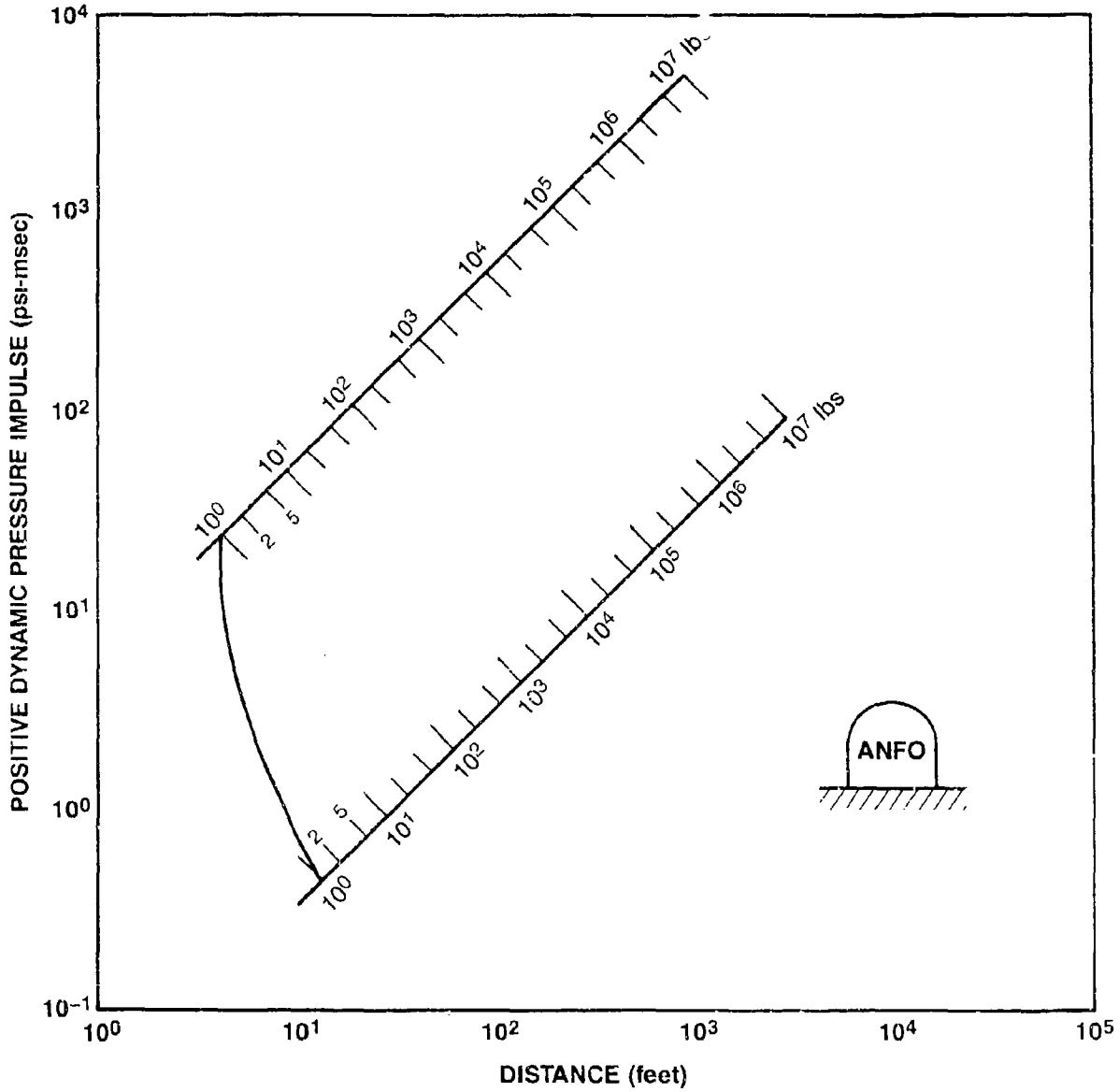
Example: For 100;000 lbs, at 200 feet, positive impulse = 750 psi-msec

ANFO Domed Cylinders (L/D = 0.75)
Positive Dynamic Pressure Impulse vs Distance



Example: For 100,000 lbs, at 200 feet, dynamic pressure = 85 psi

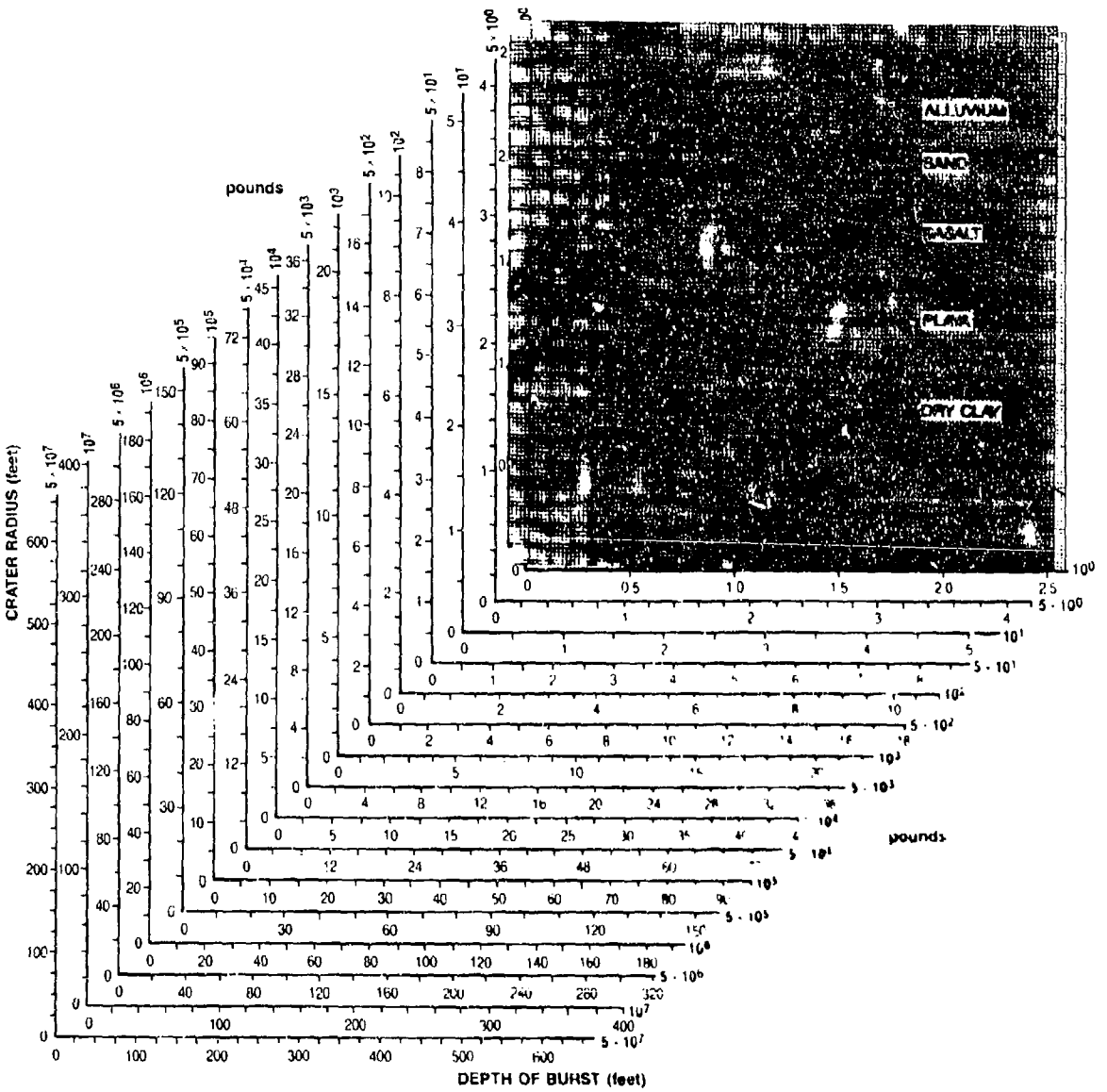
ANFO Domed Cylinders (L/D = 0.75)
Positive Dynamic Pressure Impulse vs Distance



Example: For 100,000 lbs, at 200 feet, dynamic pressure impulse = 600 psi-msec

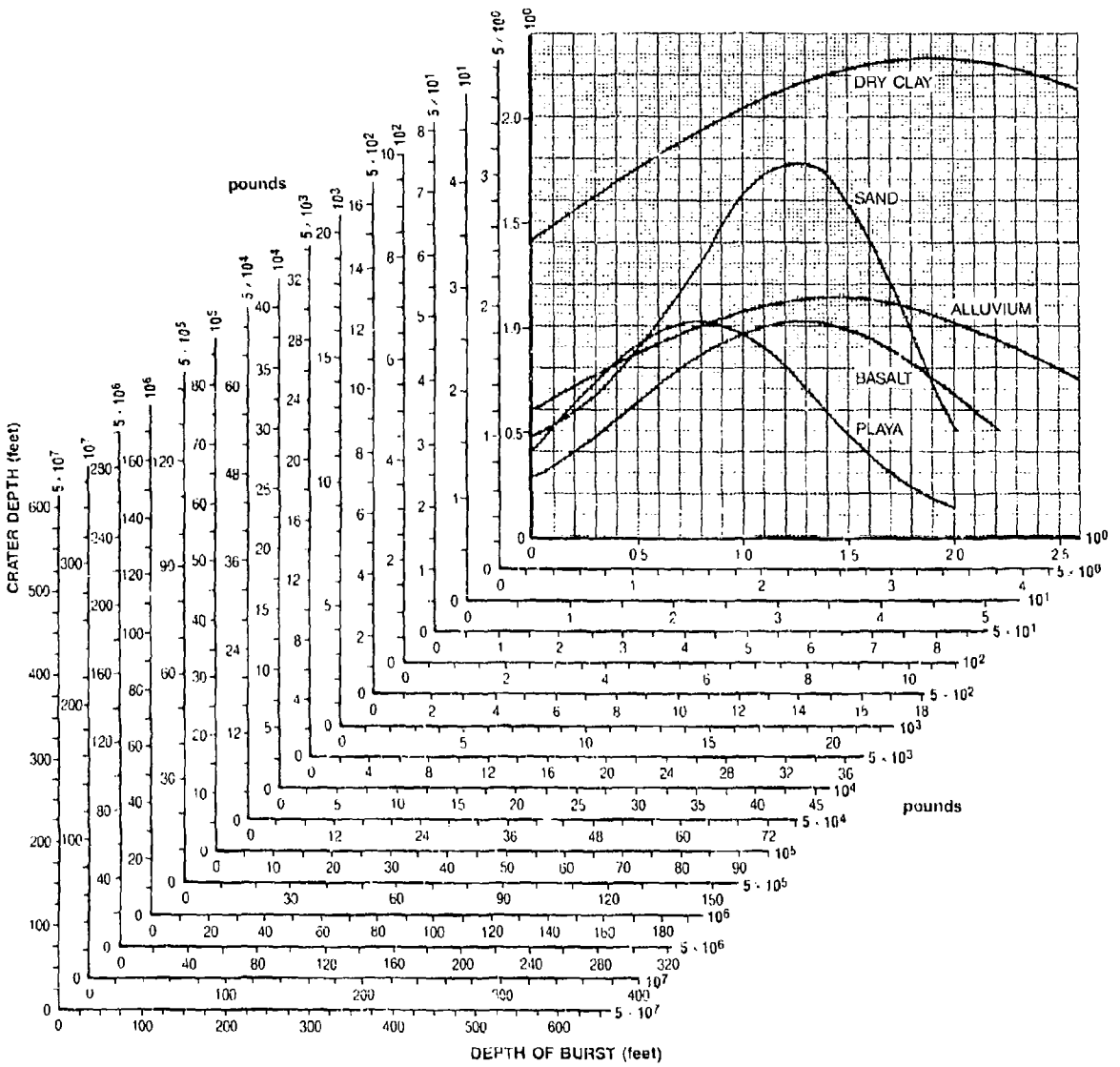
Section 2
CRATERS

TNT Spheres
Apparent Crater Radius vs Depth of Burst



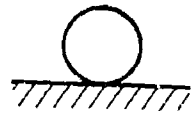
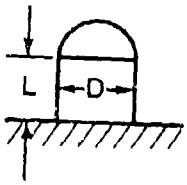
Example: For 10,000 lbs, for a depth of burst of 25 feet in dry clay, apparent crater radius = 17 feet

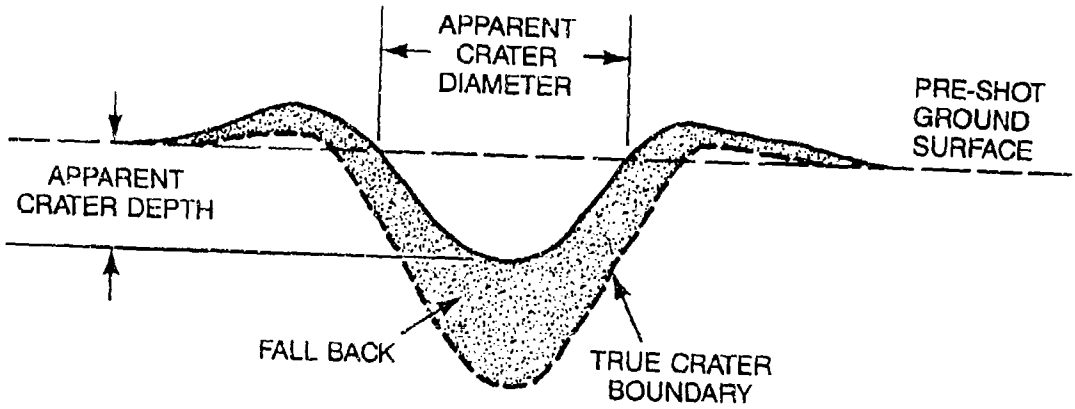
TNT Spheres
Apparent Crater Depth vs Depth of Burst



Example: For 10,000 lbs, for a depth of burst of 25 feet in dry clay, apparent crater depth = 39 feet

Multiplying Factors for Charges of Different Geometries

CHARGE GEOMETRY	RADIUS	DEPTH
 HALF BURIED SPHERE	1.0	1.0
 SURFACE TANGENT SPHERE	0.74	0.61
 HEMISPHERE	0.97	1.08
 DOMED CYLINDER (L/D = 0.75)	0.6	0.63



Apparent Crater Dimensions for Half-Buried Spheres, Surface Tangent Spheres, Hemispheres, and Domed Cylinders (L/D = 0.75)

To obtain the apparent crater radii and depths for charges of shapes other than spherical, use the spherical TNT surface burst data, i.e., depth of burst = 0, and multiply the dimensions by the values shown in the table. If the explosive is other than TNT, first determine the TNT equivalence of the test explosive (see page 23), e.g., 620 tons ANFO = 500 tons TNT.

Section 3
MISCELLANEOUS

Equivalent Weights For Peak Pressure
(Referenced to TNT)

EXPLOSIVE	EQUIVALENT WEIGHT	CHANGE IN DISTANCE FOR GIVEN PRESSURE (percent)
TNT	1.0	0
PENTOLITE	1.17	+5
TRITONAL	1.1	+3
H-6	1.31	+9
HBX	1.18	+6
ANFO (94/6)	0.82	−6
NITROMETHANE	1.0	0
DYNAMITES	0.7 to 0.9	−11 to −3

PROPELLANTS

LIQUID, e.g., LOX/H_2, $W_{TNT}\ (MAX) \approx 4\ W_P^{2/3}$

SOLID 0 to 1.25 (according to type and size)

$$EQ\ WT_{EXPL\text{''}X\text{''}} = \frac{W_{TNT}}{W_{EXPL\text{''}X\text{''}}}$$

Example: What weight of ANFO gives the same pressures as 1,000 pounds of TNT?

$$0.82_{ANFO} = \frac{1{,}000\ lbs_{TNT}}{W_{ANFO}}\ ;\quad W_{ANFO} = 1{,}219.5\ lbs$$

or 1,000 lbs TNT = 1,200 lbs ANFO

For the same weight of explosive, the distance for a given pressure is 6 percent less for ANFO than for TNT.

Scaling Procedures

As an alternative to the overlays, all the 1-pound *airblast* curves in this manual can be scaled to other, new yields via the following steps:

1. For arrival time, positive duration, and dynamic pressure impulse:
   - Determine the cube root of the new yield (weight of charge) [see page 25].
   - Divide the distance or the effects parameter of interest by this cube root to get scaled parameter.
   - On the 1-pound curve, read the value for the scaled parameter of interest (Y axis) versus the scaled distance (X axis).
   - Multiply this scaled effects value by the cube root of the new yield to obtain the answer.
2. For overpressure and dynamic pressure:
   - Determine the cube root of the new yield (weight of charge) [see page 25].
   - Divide the distance by this cube root to get scaled distance.
   - On the appropriate pressure curve, read the pressure at this scaled distance; this pressure is the answer.

Examples:

What is the arrival time at 110 feet from a 5,000-pound hemispherical TNT charge?

1. From page 25, cube root of 5,000 = 17.1
2. Scaled distance = 110/17.1 = 6.43 feet
3. From page 9, at scaled distance of 6.43 feet, scaled arrival time = 2.1 msec
4. 2.1 × 17.1 = 35.9 msec (Answer).

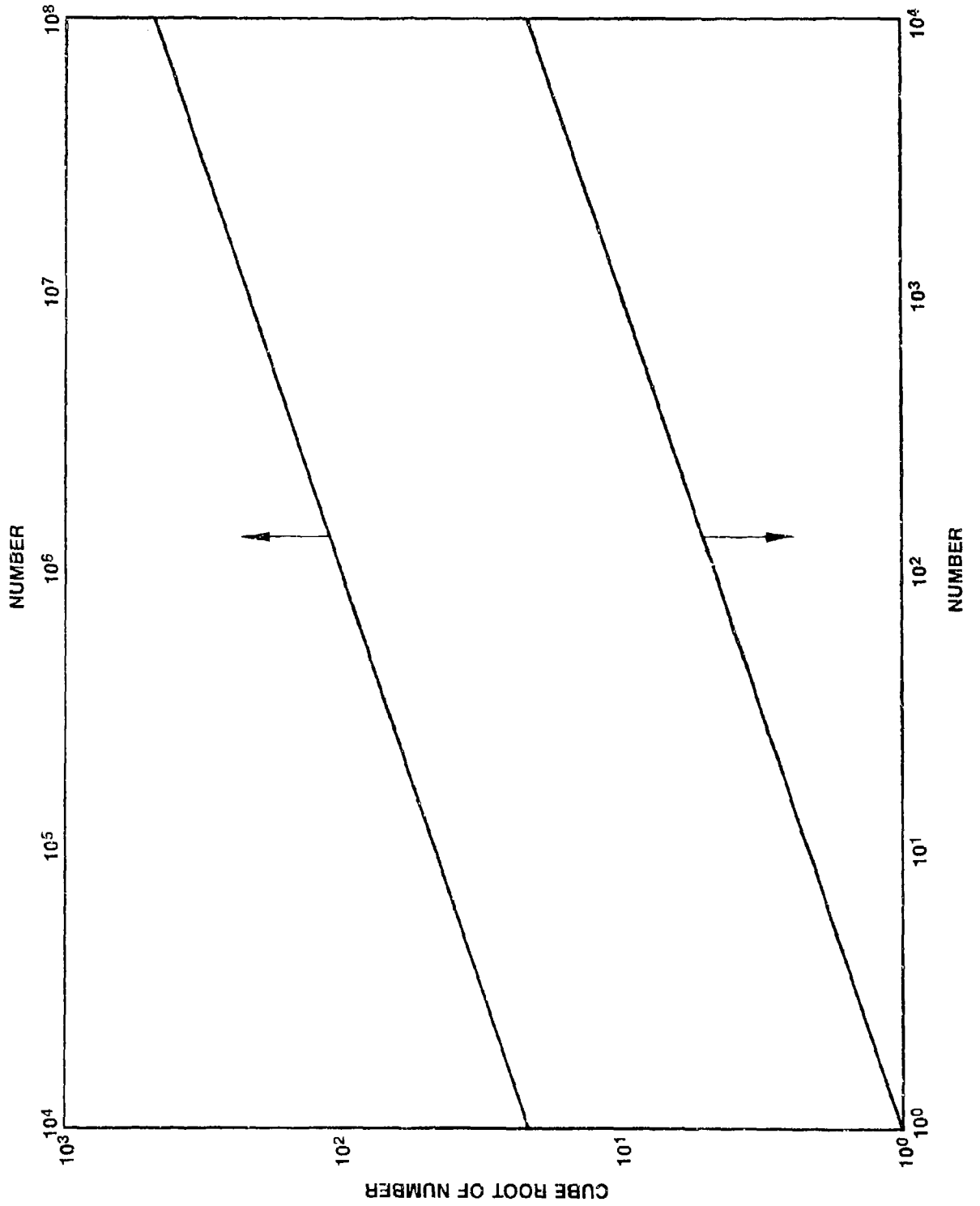
At what distance from a 5,000-pound TNT hemisphere is the arrival = 35 msec?

1. From page 25, cube root of 5,000 = 17.1
2. Scaled arrival time = 35/17.1 = 2.1 msec
3. From page 9, for scaled arrival time of 2.1 msec, scaled distance = 6.3 feet
4. 6.3 × 17.1 = 108 feet (Answer).

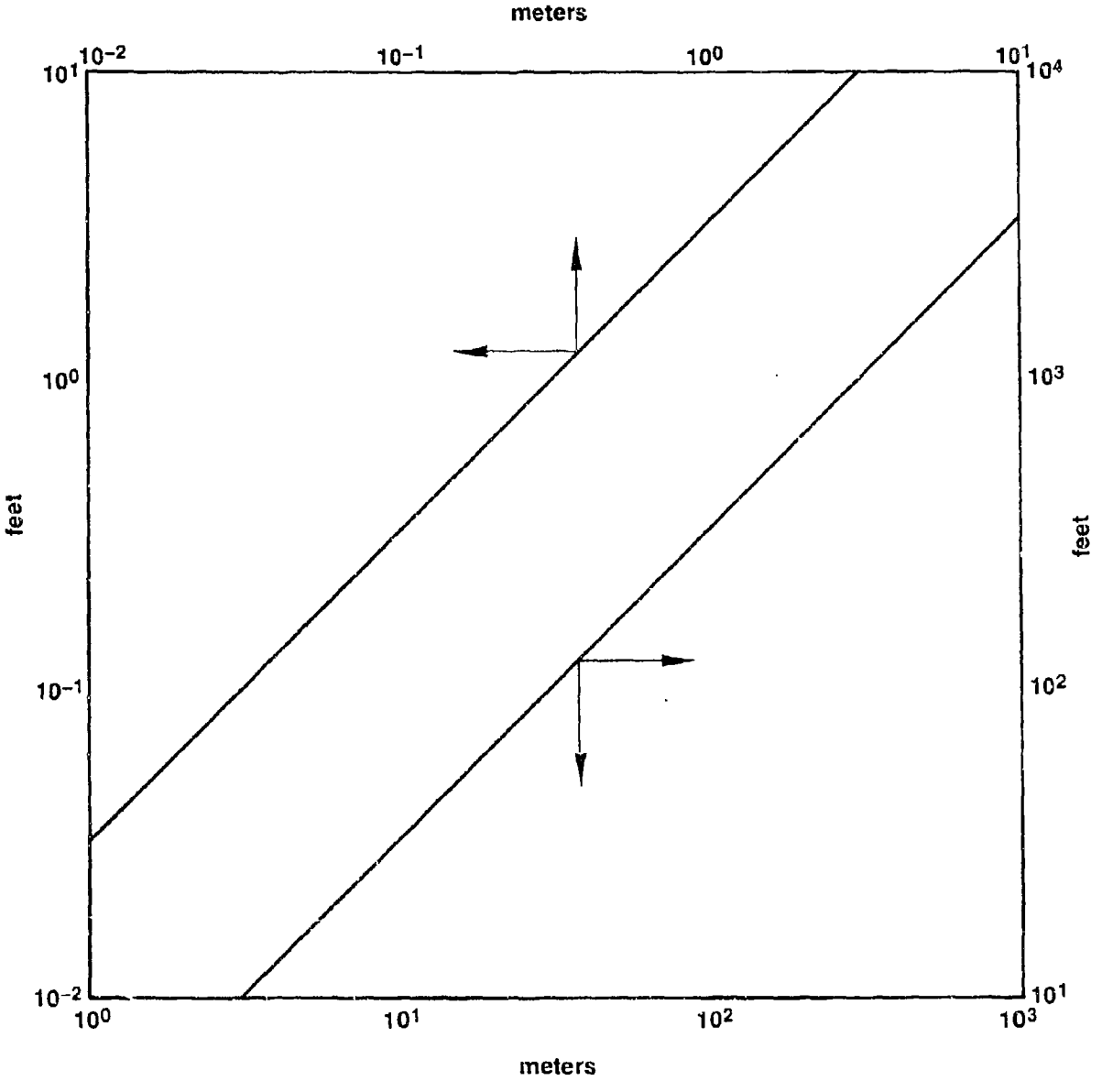
What is the pressure at 110 feet from a 5,000-pound TNT hemisphere charge?

1. From page 25, cube root of 5,000 = 17.1
2. Scaled distance = 110/17.1 = 6.43 fe
3. From page 8, at a scaled distance of 6.43 feet, the overpressure = 23 psi (Answer).

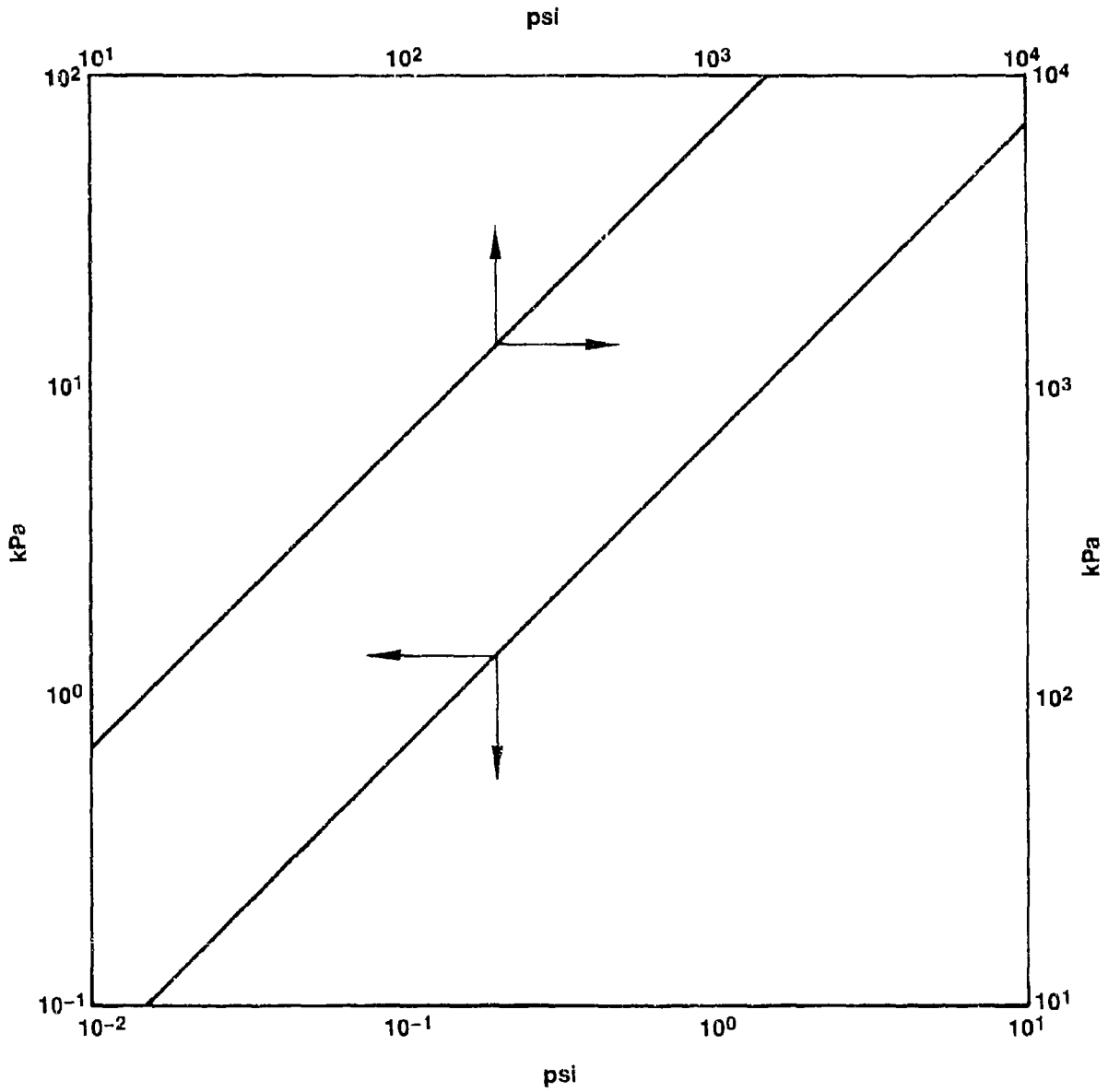
Cube Root of Numbers



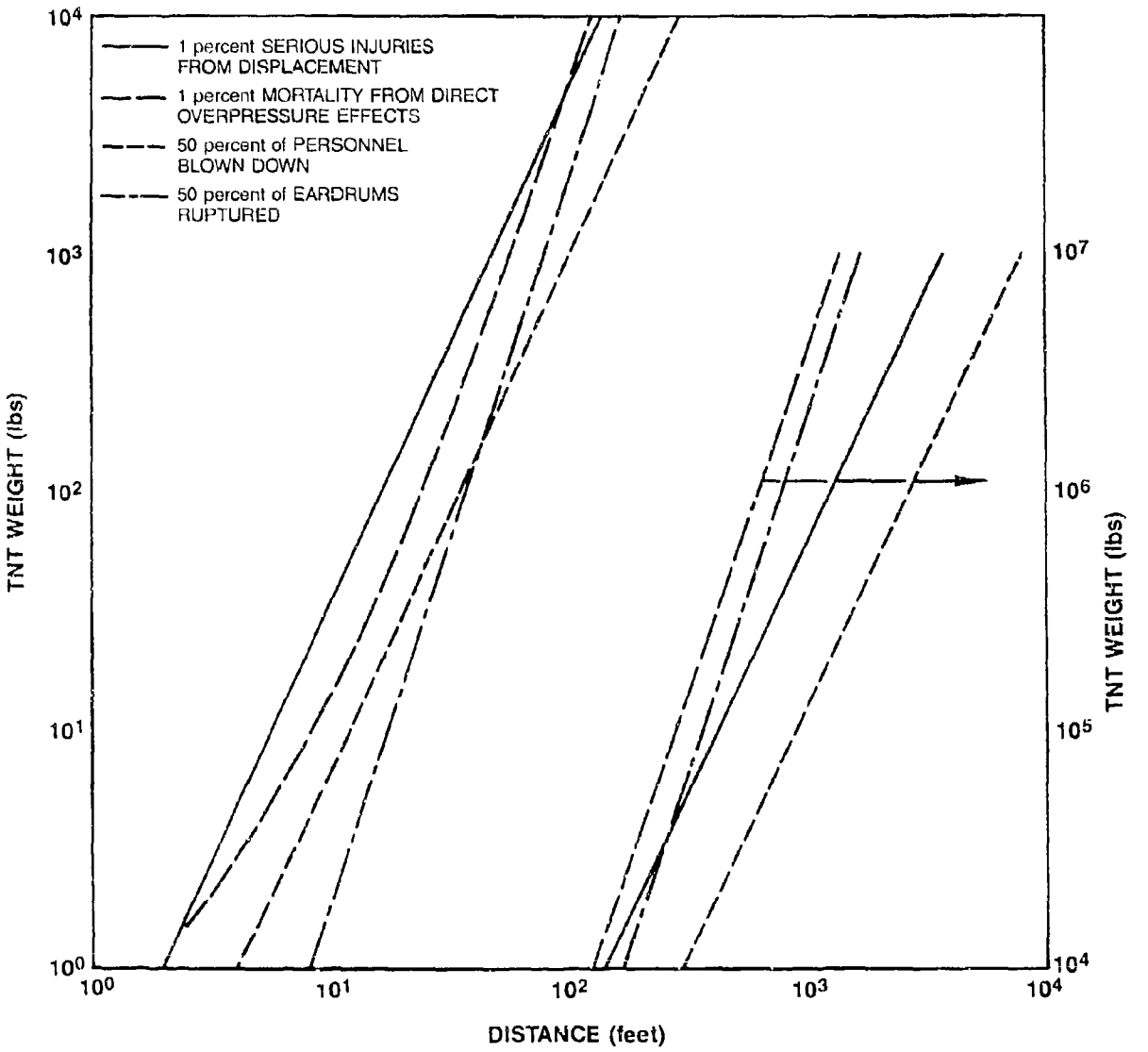
Meter/Feet Conversion



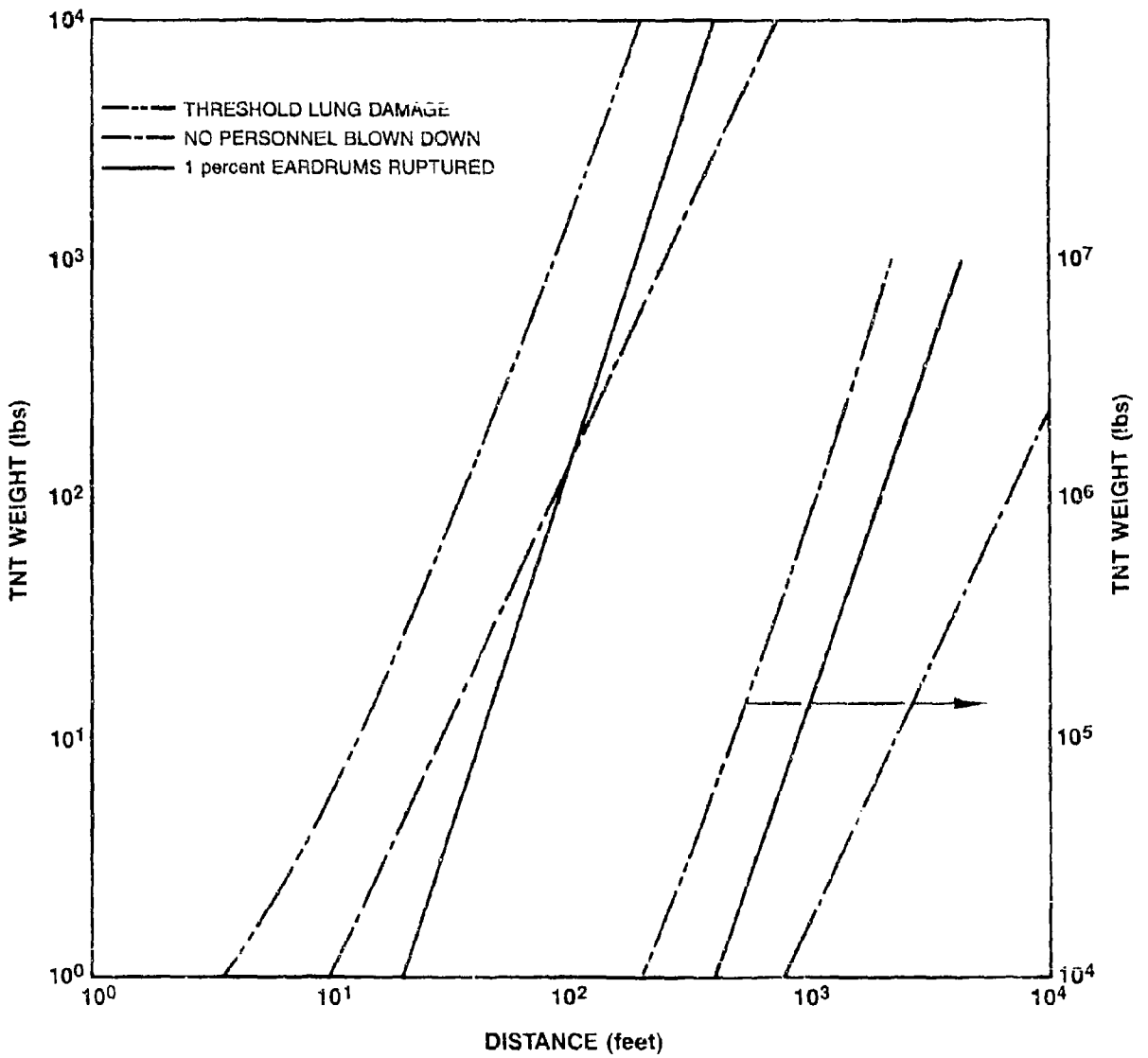
psi/kPa Conversion



Airblast Criteria for Personnel Standing in the Open
(Part 1)



Airblast Criteria for Personnel Standing in the Open (Part 2)



Section 4
SOURCES OF INFORMATION

Sources of Information

TNT Spheres (pp. 2–6), TNT Cylinders (pp. 12–13), TNT Craters (pp. 20–21)

The basic data for the indicated pages were obtained from *Explosion Effects and Properties—Part 1, Explosion Effects in Air*, M.M. Swisdak, Naval Surface Weapons Center, White Oak, Maryland, Report NSWC/WOL/TR75-116, October 1975. Other sources considered: *Structures to Resist the Effects of Accidental Explosions*, TM 5-1300/NAVFAC P-397/AFM 88-22; personal communications with R.E. Reisler, Ballistic Research Laboratories, Aberdeen, Maryland, June 1983, for height-of-burst information; *Airblast from One Pound Cylindrical Charges Positioned Vertically on the Ground*, R.E. Reisler, D.P. LeFevre, Ballistic Research Laboratories, Aberdeen, Maryland, BRL Interim Memorandum Report 42, April 1972.

Charge Shape Effect on Pressure (p. 7)

"Watch Your Equivalent Weight," J. Petes, *Proceedings of the 12th Explosives Safety Seminar*, Armed Services Explosive Safety Board, Washington, D.C., August 1970.

TNT Hemispheres (pp. 8–11)

Air Blast Parameters Versus Distances for Hemispherical TNT Surface Bursts, C.N. Kingery, BRL Report 1344, June 1966, Ballistic Research Laboratories, Aberdeen, Maryland.

ANFO Domed Cylinder (pp.14–19)

User's Guide and History of ANFO as a Nuclear Weapons Effect Simulation Explosive, J. Petes, R. Miller, R. McMullan, Kaman–Tempo, Alexandria, Virginia, KT–83-012(R), DNA-TR-82-156. This report considers the 10-year development and 7-year experimental use of unconfined (uncased) ANFO for nuclear weapon effects simulation bringing together the explosion effects of ANFO charges in one volume. *Note*: although the ANFO sheets show 1-pound curves, this is done strictly to aid scaling to larger yields. Because of the large critical diameter of unconfined ANFO charges, the curves should be used only for charges weighing 500 pounds and more. *Note also* that the curves are for a specific geometry of the charge with the ratio of the length of the cylindrical portion of the charge to the diameter equaling 0.75; the dome is hemispherical.

Charge Shape Effect on Craters (p. 22)

The information on this page was developed from an examination of crater data obtained on large tests using TNT and ANFO explosives. For the tests considered, crater diameters were within 18 percent of those measured and crater depth within 8 percent. The big problem in estimating crater dimensions in any scheme is in determining the applicable soil description.

Equivalent Weights (p. 23)

The values given for the military explosives TNT, Pentolite, Tritonal, H-6, and HBX are averages from many "standard" sources. The ANFO and dynamites equivalent weights are from NSWC/WOL/TR 75-116; for nitromethane, the value comes from *Pre-Mine Throw IV—Free Field Experiment*, G. Teel, Ballistic Research Laboratories, Aberdeen, Maryland, POR-6830, August 1975; for liquid propellants, "A Simplified Method for Estimating the Appropriate TNT Equivalent Weight from Liquid Propellant Explosions," *Proceedings of the 15th Annual Explosives Safety Seminar, September 1973*, L.D. Sutherland; and for solid propellants, *Maximum TNT Equivalence of Naval Propellants*, M.M. Swisdak, Naval Surface Weapons Center, White Oak, Maryland, NSWCTR 83-120, February 1983. *Note*: equivalent weight values are averages over a limited range of pressures, perhaps a few hundred to a few psi.

Scaling Procedure (p. 24)

The curves for the effects of 1 pound of explosive are the usually presented "scaled" curves with the X- and Y-axes showing the scaled parameters (except for pressure, which cannot be scaled). Page 7 is an example of the traditional presentation of scaled curves.

Personnel Criteria (pp. 28–29)

"Blast Criteria for Personnel in Relation to Quantity–Distance," *Proceedings of the 13th Annual Explosives Safety Seminar*, D.R. Richmond and E.R. Fletcher, Armed Services Explosive Safety Board, Washington, D.C., September 1971.

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE

ASSISTANT TO THE SECRETARY OF DEFENSE
ATOMIC ENERGY
ATTN: EXECUTIVE ASSISTANT

DEF RSCH & ENGRG
ATTN: STRAT & THTR NUC FOR (O&SS)

DEFENSE ADVANCED RSCH PROJ AGENCY
ATTN: DIR (STRAT TECH OFF)

DEFENSE INTELLIGENCE AGENCY
ATTN: DI-7D
ATTN: DT 1
ATTN: DT-1B
ATTN: DT-2
ATTN: RTS-2A (TECH LIB)
ATTN: RTS-2B

DEFENSE NUCLEAR AGENCY
ATTN: DFRA
ATTN: NANF
ATTN: NASF
ATTN: NAWE
ATTN: OPNA
ATTN: OPNS
ATTN: RAAE
ATTN: RAEE
ATTN: RAEV
ATTN: SPST
ATTN: SPWE
ATTN: TDTR
4 CYS ATTN: TITL

DEFENSE TECHNICAL INFORMATION CENTER
12 CYS ATTN: DD

DEPARTMENT OF DEFENSE EXPLO SAFETY BOARD
ATTN: CHAIRMAN

FIELD COMMAND DEFENSE NUCLEAR AGENCY
ATTN: FCPRW
ATTN: FCT
ATTN: FCTP
ATTN: FCTXE
ATTN: FTSM
ATTN: FTTD

FIELD COMMAND DNA DET 2
LAWRENCE LIVERMORE NATIONAL LAB
ATTN: FC-1

JOINT CHIEFS OF STAFF
ATTN: J-5 NUCLEAR & CHEMICAL DIV
ATTN: JAD
ATTN: JOINT ANALYSIS DIRECTORATE

JOINT STRAT TGT PLANNING STAFF
ATTN: JKCS

NATIONAL SECURITY AGENCY
ATTN: R-1 E BUTALA
ATTN: W14

DEPARTMENT OF THE ARM

ADV ANTITANK WEAPON SYS PROJ OFF (PROV)
ATTN: PROJECT MANAGER

AIR DEF COMM & CONTROL SYS
ATTN: PROJECT MANAGER

AIRCRAFT SURVIVABILITY EQUIPMENT
ATTN: PROJECT MANAGER

AMCPM-GARS-TMD
ATTN: PROJECT MANAGER

ARMORED COMBAT VEHICLE TECH
ATTN: PROJECT MANAGER

ARMY HELICOPTER IMPROV PROG (AHIP-PRO)
ATTN: PROJECT MANAGER

ARMY LOGISTICS MANAGEMENT CTR
ATTN: COMMANDANT

BLACK HAWK
ATTN: PROJECT MANAGER

CANNON ARTILLERY WEAPONS SYS
ATTN: AMCPM-CAWS-S

CH-47 MODERNIZATION PROGRAM
ATTN: PROJECT MANAGER

CHAPARRAL/FARR
ATTN: AMCPM-CF

COBRA
ATTN: AMCPM-CO

COMMERCIAL CONST. EQUIPMENT &
ATTN: PROJECT MANAGER

DEFENSE COMMUNICATIONS SYSTEMS
ATTN: PROJECT MANAGER

DEP CH OF STAFF FOR OPS & PLANS
ATTN: DAMO-NCN

DEP CH OF STAFF FOR RSCH DEV & ACQ
ATTN: DAMA-ART
ATTN: DAMA-CSM-N

DEPUTY CHIEF OF STAFF FOR LOGISTICS
ATTN: DALO-SMA

FIGHTING VEHICLE SYSTEMS
ATTN: PROJECT MANAGER

FIREFINDER/REMBASS
ATTN: PROJECT MANAGER

HARRY DIAMOND LABORATORIES
ATTN: SCHLD-NW-P
ATTN: SCLHD-DTSO
ATTN: SLCIS-IM-TL (TECH LIB)

HAWK
ATTN: AMCPM-HA-SE-MS

HEAVY EQUIPMENT TRANSPORTER SYS
ATTN: PROJECT MANAGER

HELLFIRE/GROUND LASER DESIGNATORS (AMCPM-HD)
ATTN: PROJECT MANAGER

IMPROVED TOW VEHICLE READINESS
ATTN: PROJECT MANAGER

JOINT STARS
ATTN: AMCPM-JS-TM (B DANESE)

JOINT TACTICAL FUSION PROG (PROV)
ATTN: JTF-SET AMP TEST

LIGHT COMBAT VEHICLES
ATTN: PROGRAM MANAGER

MOBILE ELECTRIC POWER
ATTN: PROJECT MANAGER

MOBILE SUBSCRIBER EQUIPMENT (MSE)
ATTN: AMCPM-MSE

MODULAR INTERGRATED COMM & NAV SYS
ATTN: PROJECT MANAGER

MULTI SERVICE COMMUNICATIONS SYS
ATTN: AMCPM-MSCS-PM

MULTIPLE LAUNCH ROCKET SYSTEM
ATTN: PROJECT MANAGER

M113/M113A1 FAMILY OF VEH READINESS
ATTN: PROJECT MANAGER

M60 TANKS (AMCPM-M60)
ATTN: AMCPM-M60

M9/UET
ATTN: PROJECT MANAGER

OFFICE OF THE PROJECT MANAGER
ATTN: AMCPM-NUC-A (C KRIESER)

OPERATIONS TACTICAL DATA SYS
ATTN: PROJECT MANAGER

PATRIOT
ATTN: PROJECT MANAGER

PERSHING SYSTEM
ATTN: PROJECT MANAGER

POSITION LOCATION REPORTING SYS/
ATTN: AMCPM-PL

RESEARCH & DEV CENTER
ATTN: COMMANDER

SATELLITE COMMUNICATIONS
ATTN: PROJECT MANAGER

SMOKE/OBSCURANCE
ATTN: PROJECT MANAGER

SPECIAL ELEC MISSION AIRCRAFT
ATTN: AMCPM-AE

STINGER
ATTN: PROJECT MANAGER

TACTICAL AIRBORNE REMOTELY
ATTN: AMCPM-OTDS

TANK MAIN ARMAMENT SYSTEM
ATTN: PROJECT MANAGER

TARGET ACQUISITION DESIGNATION SIGHT/
ATTN: PROJECT MANAGER

TOW, AMCPM-TO
ATTN: PROJECT MANAGER

U S ARMY ARMAMENT RSCH & DEV CENTER
ATTN: SMCAR-FSM-E
ATTN: SMCAR-LCN-C
ATTN: SMCAR-ST

U S ARMY ATMOSPHERIC SCIENCES LAB
ATTN: SLCAS-AE
ATTN: SLCAS-AE-E

U S ARMY AVIATION SYSTEMS CMD
ATTN: COMMANDER

U S ARMY BALLISTIC RESEARCH LAB
ATTN: AMXBR-OD-ST
ATTN: DRBAR-BLE
ATTN: DRDAR-BLT

U S ARMY BELVOIR R&D CTR
ATTN: STRBE-A01

U S ARMY CHEMICAL RSCH & DEV CTR
ATTN: SMCCR-PPC

U S ARMY COMMUNICATIONS COMMAND
ATTN: COMMANDER

U S ARMY CONSTRUCTION ENGRG RES LAB
ATTN: CERL-PP

U S ARMY CORPS OF ENGINEERS
ATTN: DAEN-ECE-T
ATTN: DAEN-RDM
ATTN: DAEN-ZCM

U S ARMY ELCT WARF/REC SURV & TARG ACQ CTR
ATTN: AMSEL-EW-D

U S ARMY ELECTRONICS R & D COMD
ATTN: COMMANDER

U S ARMY ELECTRONICS R & D COMMAND
ATTN: AMC-PM-JS-PA
ATTN: DELET-ER

U S ARMY ENGR WATERWAYS EXPER STATION
ATTN: WESGH
ATTN: WESGR
ATTN: WESSD
ATTN: WESSE, J K INGRAM
ATTN: WESSS

U S ARMY FOREIGN SCIENCE & TECH CTR
ATTN: DRXST-SD1

U S ARMY HEALTH SERVICES COMMAND
ATTN: HSOP-SO

U S ARMY MATERIAL COMMAND
ATTN: AMCCN-N
ATTN: DRXAM-TL (TECH LIB)
ATTN: OFFICE OF PROJ MANAGEMENT

U S ARMY MATERIAL TECHNOLOGY LABORATORY
ATTN: AMXNR-P

U S ARMY MATERIEL SYS ANALYSIS ACTVY
ATTN: AMXSY-CR

U S ARMY MISSILE COMMAND
ATTN: AMCPM-HAE
ATTN: AMCPM-PE
ATTN: AMCPM-RDL-E
ATTN: AMCPM-RSTT
ATTN: DOCUMENTS, AMSMI-RD-CS-R

U S ARMY NATICK RSCH DEV & ENGRG CENTER
ATTN: DRNC-UST

U S ARMY NUCLEAR & CHEMICAL AGENCY
ATTN: MONA-NU

U S ARMY OPERATIONAL TEST & EVAL AGY
ATTN: COMMANDER

U S ARMY SATELLITE-COMM AGENCY
ATTN: AMCPM-SC-9B
ATTN: TECHNICAL LIBRARY

U S ARMY STRATEGIC DEFENSE CMD
ATTN: DACS-BMT/S
ATTN: DASD-DP
ATTN: DASD-PP
ATTN: DASD-TD

U S ARMY STRATEGIC DEFENSE CMD
ATTN: ATC-D
ATTN: BMDSC-H
ATTN: BMDSC-LEH
ATTN: DASD-H-L

U S ARMY TEST AND EVALUATION COMD
ATTN: DRSTE-CM-F R GALASSO

U S ARMY TROOP SUPPORT COMMAND
ATTN: AMSTR-E

U S ROLAND
ATTN: PROJECT MANAGER

U S TANK COMMAND
ATTN: AMCPM-GCM-QT
ATTN: AMCPM-LA
ATTN: AMCPM-LCV-QT
ATTN: AMCPM-TVH

US ARMY WHITE SANDS MISSILE RANGE
ATTN: STEWS-FE-R
5 CYS ATTN: STEWS-TE-AN J OKUMA
ATTN: STEWS-TE-N

USA ELECT WARFARE/SEC,SURV & TARGET ACQ CTR
ATTN: AMSEL EW-MD
ATTN: DELCS K

USA ORD MISSILE & MUNITIONS CTR & SCHOOL
ATTN: ATSK-MS

DEPARTMENT OF THE NAVY

DAVID TAYLOR NAVAL SHIP R & D CTR
ATTN: CODE 174
ATTN: STRUCTURES DEPT

DAVID TAYLOR NAVAL SHIP R & D CTR
ATTN: CODE 770

JOINT CRUISE MISSILES PROJECT OFC (PM-3)
ATTN: JCM-NS-1

MARINE CORPS
ATTN: CODE POG-31

NAVAL CIVIL ENGINEERING LABORATORY
ATTN: L51 J TANCRETO
ATTN: L51P1 W KEENAN

NAVAL COASTAL SYSTEMS CENTER
ATTN: CODE 4210

NAVAL FACILITIES ENGINEERING COMMAND
ATTN: COMMANDER

NAVAL MATERIAL COMMAND
ATTN: MAT-0323

NAVAL OCEAN SYSTEMS CENTER
ATTN: CODE 825

NAVAL RESEARCH LABORATORY
ATTN: CODE 2627 (TECH LIB)
ATTN: CODE 7780

NAVAL SEA SYSTEMS COMMAND
ATTN: SEA-55X1

NAVAL SURFACE WEAPONS CENTER
ATTN: CODE H21
ATTN: CODE R15

NAVAL SURFACE WEAPONS CENTER
ATTN: COMMANDER

NAVAL WEAPONS CENTER
ATTN: COMMANDER

NAVAL WEAPONS EVALUATION FACILITY
ATTN: DIRECTOR

OFC OF THE DEPUTY CHIEF OF NAVAL OPS
ATTN: OP 62
ATTN: OP 654(STRAT EVAL & ANAL BR)
ATTN: OP 981

OFFICE OF CHIEF OF NAVAL OPERATIONS
ATTN: OP-622C
ATTN: OP-981

STRATEGIC SYSTEMS PROGRAM OFFICE (PM-1)
ATTN: DIRECTOR
ATTN: SP-272

DEPARTMENT OF THE AIR FORCE

AERONAUTICAL SYSTEMS DIVISION
ATTN: ASD/ENSS

AIR FORCE ARMAMENT LABORATORY
ATTN: AFATL/DLJE

AIR FORCE ENGINEERING & SERVICES CTR
ATTN: RDCS
ATTN: RDCS BUCHHOLTZ
ATTN: S HAWN/RDCM

AIR FORCE GEOPHYSICS LABORATORY
ATTN: LY
ATTN: LYC
ATTN: XOP

AIR FORCE INSPECTION & SAFETY CENTER
ATTN: AFISC/SEV

AIR FORCE INSTITUTE OF TECHNOLOGY/EN
ATTN: LIBRARY/AFIT/LDEE

AIR FORCE LOGISTICS COMMAND
ATTN: COMMANDER

AIR FORCE OPERATIONAL TEST & EVAL CTR
ATTN: TEZ

AIR FORCE ROCKET PROPULSION LAB
ATTN: COMMANDANT

AIR FORCE SYSTEMS COMMAND
ATTN: DLWN (MAJ WALTHAM)
ATTN: TEVA

AIR FORCE TECHNICAL APPLICATIONS CTR
ATTN: TNT

AIR FORCE WEAPONS LABORATORY, NTAAB
ATTN: NTE
ATTN: SUL

AIR FORCE WRIGHT AERONAUTICAL LAB
ATTN: COMMANDANT

AIR FORCE WRIGHT AERONAUTICAL LAB
ATTN: AFWAL/MLBC

AIR UNIVERSITY LIBRARY
ATTN: AUL-LSE

BALLISTIC MISSILE OFFICE/DAA
2 CYS ATTN: ENSN
ATTN: ENSR
ATTN: MYE

DEPUTY CHIEF OF STAFF/AF-RDQM
ATTN: AF/RDQI

DEPUTY CHIEF OF STAFF/XOO
ATTN: AF/XOOTS

ELECTRONIC SECURITY COMMAND
ATTN: COMMANDER

ELECTRONIC SYSTEMS DIV/OCMS
ATTN: OCMS

HQ USAF/XOXFS
ATTN: AFXOOTS

HUMAN SYSTEMS DIVISION (AFSC)
ATTN: COMMANDER
ATTN: YAX

MILITARY AIRLIFT COMMAND
ATTN: MACOS/XNOD
ATTN: MACOS/XOND

ROME AIR DEVELOPMENT CENTER, AFSC
ATTN: RADC/DCCL

SPACE & MISSILE TEST CENTER, AFSC
ATTN: COMMANDER

STRATEGIC AIR COMMAND/INTCS
ATTN: INTCS

544 IAS/IAAT
ATTN: IAAT

DEPARTMENT OF ENERGY

DEPARTMENT OF ENERGY
ATTN: R L HYMES, ODP

DEPARTMENT OF ENERGY
ATTN: OMA/DP-225

DEPARTMENT OF ENERGY
ATTN: NEJ5

LAWRENCE LIVERMORE NATIONAL LAB
ATTN: L-22
ATTN: L-81

LOS ALAMOS NATIONAL LABORATORY
ATTN: D RICHMOND
ATTN: T T S COLMAN

OAK RIDGE NATIONAL LABORATORY
ATTN: O P ZIMMERMAN

SANDIA NATIONAL LABORATORIES
ATTN: ORG 7100 C D BROYLES

OTHER GOVERNMENT

FEDERAL EMERGENCYS MANAGEMENT AGENCY
ATTN: INDUSTRIAL PROT DIV/NP

U S COAST GUARD
ATTN: G-MHM

DEPARTMENT OF DEFENSE CONTRACTORS

APTEK, INC
ATTN: H LINDBERG

BOEING CO
ATTN: M/S 17-04
ATTN: M/S 85-20

BOEING TECHNICAL & MANAGEMENT SVCS, INC
ATTN: E YORK

CALIFORNIA RESEARCH & TECHNOLOGY, INC
ATTN: K KREYENHAGEN

CARPENTER RESEARCH CORP
ATTN: H J CARPENTER

DENVER COLORADO SEMINARY UNIVERSITY OF
ATTN: J WISOTSKI
ATTN: L BROWN

INSTITUTE FOR DEFENSE ANA' YSES
ATTN: STD

KAMAN SCIENCES CORP
ATTN: E CONRAD

KAMAN TEMPO
ATTN: DASIAC

KAMAN TEMPO
ATTN: DASIAC
2 CYS ATTN: J PETES

LOCKHEED MISSILES & SPACE CO, INC
ATTN: K S MYERS

MCDONNELL DOUGLAS CORP
ATTN: D NEWLANDER
ATTN: J TRACYS
ATTN: L COHEN

NEW MEXICO ENGINEERING RESEARCH INSTITUTE
ATTN: G LANE

PACIFIC SIERRA RESEARCH CORP
ATTN: H BRODE, CHAIRMAN SAGE

PHYSICS INTERNATIONAL CO
ATTN: DIRECTOR

R & D ASSOCIATES
ATTN: F A FIELD

RAND CORP
ATTN: R SOLOMON

S-CUBED
ATTN: R DUFF

SCIENCE APPLICATIONS INTL CORP
ATTN: J DISHON

SCIENCE APPLICATIONS INTL CORP
ATTN: J COCKAYNE

SPECTRON DEVELOPMENT LABATORIES, INC
ATTN: D MODARRESS

TECH REPS, INC
ATTN: J KEEFER

TERRA TEK, INC
ATTN: S GREEN

TRW ELECTRONICS & DEFENSE SECTOR
ATTN: N LIPNER

WEIDLINGER ASSOC., CONSULTING ENGRG
ATTN: T DEEVY

FOREIGN

ADMIRALTY SURFACE WEAPONS ESTAB (ASWE)
ATTN: C JONES

AMT FUR STUDEIN UND UBUNGEN
ATTN: DIRECTOR

AUSTRALIA EMBASSY
ATTN: OFFICE OF THE DEF SCI ATTACHE

BRITISH DEFENCE STAFF
ATTN: ACOW
ATTN: DR MITCHELL
ATTN: MR LEYS
ATTN: RARE (MR GRIFFITHS)

BUNDESMINISTERIUM DE VERTEIDIGUNG
ATTN: R SHILLING

CANADIAN EMBASSY
ATTN: CDRD

DEFENSE RESEARCH ESTABLISHMENT
ATTN: HEAD/MILITARY ENGRG SECTION

DIRECTOR TECHNOLOGY RESEARCH
ATTN: H PASMAN

ERNST-MACH-INSTITUT
ATTN: H REICHENBACH

INQENIUR EN CHEF DE L'ARMEMENT DRET/SDNBC
ATTN: COL ISTIN

MILITARY ATTACHE STAFF
ATTN: AIR ATTACHE
ATTN: MILITARY ATTACHE

NATIONAL DEFENCE HEADQUARTERS
ATTN: DGMEM/DMES 3, MR BEZEMER

NATIONAL DEFENCE RESEARCH INSTITUTE
ATTN: H AXELSSON

NORWEGIAN DEFENCE CONSTRUCTION SERVICE
25 CYS ATTN: A JENSSEN

NORWEGIAN EMBASSY
ATTN: MILITARY ATTACHE

ROYAL FORTIFICATION ADMINISTRATION
ATTN: B VRETBLAD

ROYAL SWEDISH FORTIFICATION ADMIN
ATTN: DIRECTOR GENERAL

SWEDISH EMBASSY
ATTN: OFF OF THE ARMED FOR ATTACHES

WEHRWISSENSCHAFTLICHE DISENSTSELLE
ATTN: H KRUGER