TG No. 135

UNITED STATES ARMY ENVIRONMENTAL HYGIENE AGENCY

ABERDEEN PROVING GROUND, MD 21010

SENTINEL of HEALTH

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DATA BASE FOR ASSESSING THE ANNOYANCE OF THE NOISE OF SMALL ARMS

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HSHB-OB/WP Technical Guide No. 135

This guide has been developed to provide data base for use in the USAEHA small arms range noise annoyance assessment procedure. Suggested modification or ideas for improving this technical guide are solicited. Users are invited to send comments on DA Form 2028 (Recommended Changes to Publications and Forms) to Commander US Army Environmental Hygiene Agency, ATTN: HSHB-OB, Aberdeen Proving Ground, MD 21010

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REPLY TO
ATTENTION OF

HSHB-OB/WP, Technical Guide No. 135 June 1983

DATA BASE FOR ASSESSING THE ANNOYANCE OF THE NOISE OF SMALL ARMS

Local supplementation of this guide is prohibited, except upon approval of the US Army Environmental Hygiene Agency.

DATA BASE FOR ASSESSING THE ANNOYANCE OF THE NOISE OF SMALL ARMS

CHAPTER 1

GENERAL

1-1. AUTHORITY. The need for assessing the noise environment of Army small arms ranges is established in AR 200-1, Environmental Protection and Enhancement, and AR 210-20, Master Planning for Army Installations.

1-2. INTRODUCTION.

a. The levels in this guide are not generally useful for defining the occupational noise exposure of persons using military or commercial small arms. The reason is that all levels have been normalized to the 7.62 mm NATO rifle and the center of the noise source which is the muzzle. In contrast, an assessment of an occupational noise exposure must be based on the noise level at the ear of the firer. Given that the current guide addresses weapons with gun tubes as short as 2 inches and longer than 6 feet, variation at the firer's ear will be considerable. Persons interested in noise levels at the ear should use this Agency's complementary guide, TG-040 (reference 9, Appendix A).

b. Some of the noise studies referenced in this guide do not contain enough noise measurements to constitute an adequate statistical sample of the weapon being studied. These studies were used because they were the best available. As better studies become available, the assigned levels will be revised.

1-3. PURPOSE. The purpose of this guide is to provide a data base for use in the US Army Environmental Hygiene Agency small arms range noise annoyance assessment procedure. That procedure is addressed in the current guide. In the current guide, users are provided with an explanation of why specific weapons have been assigned specific noise levels.

1-4. REFERENCES. References used in this guide are listed in Appendix A.

1-5. DEFINITIONS.

a. Attenuation. A reduction in measured noise level.

b. Caliber. Bore of a gun tube in inches.

c. Decibel (dB). The unit used to express relative sound pressure levels. The reference level is 20 micropascals.

d. Decibels Peak Sound Pressure Level (dBP). The highest level of an impulsive event as measured on a storage oscilloscope or an impulse precision sound level meter with linear weighting.

CHAPTER 2

DATA BASE FOR ASSESSING THE NOISE OF SMALL ARMS

2-1. PROCEDURE.

a. The procedure was to normalize all weapons to the 7.62 mm NATO rifle (e.g., the US Army M14). Thus, all weapons noise levels have been expressed in dB relative to the NATO rifle.

b. The primary reason for anchoring all small arms to the M14 is that this weapon represents the best available data base. This data base came from a study by L. L. Pater of the Naval Surface Weapons Center (Reference 2, Appendix A). To insure a high quality data base, Pater took three precautions:

(1) He measured with equal probability at 20 degree azimuths around the weapon.

(2) He measured during weather conditions when the atmosphere came closest to homogeneity and when variability in propagation was lowest (nighttime, still air).

(3) He used two rifles, one with and one without a bullet trap so that he could separate the noise of propellant blast from the noise of the supersonic projectile shockwave.

From this carefully-gathered data base, Pater was able to develop a mathematical model for how far field noise varies around an unmuzzled gun tube. This model is:

$$L(\theta) = D_0 \cos \gamma_0 (1 + \cos \theta) / 2 + L_n$$

where

$L(\theta)$ is the dB level at azimuth θ to the direction of fire

D_0 is the front to back difference in dB (normally 14 dB)

L_n is the level immediately behind the weapon at some distance

γ_0 is the elevation of the gun in degrees

2-2. DECISIONS.

a. 7.62 mm Weapons.

(1) A decision was made to treat all 7.62 mm weapons as equal. This decision was based on a theoretical argument and an empirical demonstration. The theoretical argument came from a study by Schomer et al (Reference 4, Appendix A) which showed that the amount of noise is a function of propellant weight and the length of gun tube. Since most of the US Army's 7.62 mm weapons have the same gun tube length (Table 1), their noise level should be the same when firing the same ammunition.

TABLE 1. 7.62 mm WEAPONS USED BY THE US ARMY

Type	Use	Tube Length
M14	Rifle (replaced by M16)	22 inches
M60	Machine gun	22.75 inches w/socket
M73	Tank machine gun (obsolete)	22 inches
M219	Tank machine gun	22 inches
M134	Six barrel minigun	22 inches

(2) The empirical demonstration came from a study conducted at Fort McClellan (Reference 10, Appendix A) in which measurements of the M60 machine gun were made at distances between 3.4 and 72 meters. These data (corrected by Pater's model to an azimuth of 180 degrees) are shown in Table 2 along with a best fit linear equation to describe the attenuation as a function of distance. In the Figure, these same data have been plotted alongside the attenuation curve for the NATO rifle used in the computer program. At distances where variability is low (distances less than 10 meters), the M60 data fall with equal probability above and below the M14 curve.*

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* Persons familiar with acoustics will note that the best fit curve for the M60 data shows a drop of 4.22 dB per doubling of distance from the source, whereas, one would ordinarily expect a drop of at least 6 dB. The probable reason is that the data were taken on automatic fire. Thus, the measurements represent the noisiest event in a burst of rounds. As shown by Bullen and Hede (Reference 12, Appendix A), small arms noise shows a standard deviation of 5.6 dB between 100 and 800 yards distance. Since the statistical variance of blasts increases with distance (Reference 6, Appendix A), one can expect a greater disparity between the noisiest and average blast to increase with distance.

TABLE 2. PEAK LEVELS OF THE M60

Distance to the Muzzle (meters)	Level (dBP)	Source of Data (Table)
3.4	142	E6
5.2	140	E6
5.5	132	E6
7.2	133	E6*
18.0	134	E12*
2.9	148	E12
5.0	143	E12
6.6	141	E12
8.0	140	E12
14.0	136	E12
22.0	131	E12
22.0	133	E12
72.0	126	E12
24.0	132	E12
40.0	124	E12

* Values corrected to 180 degrees azimuth

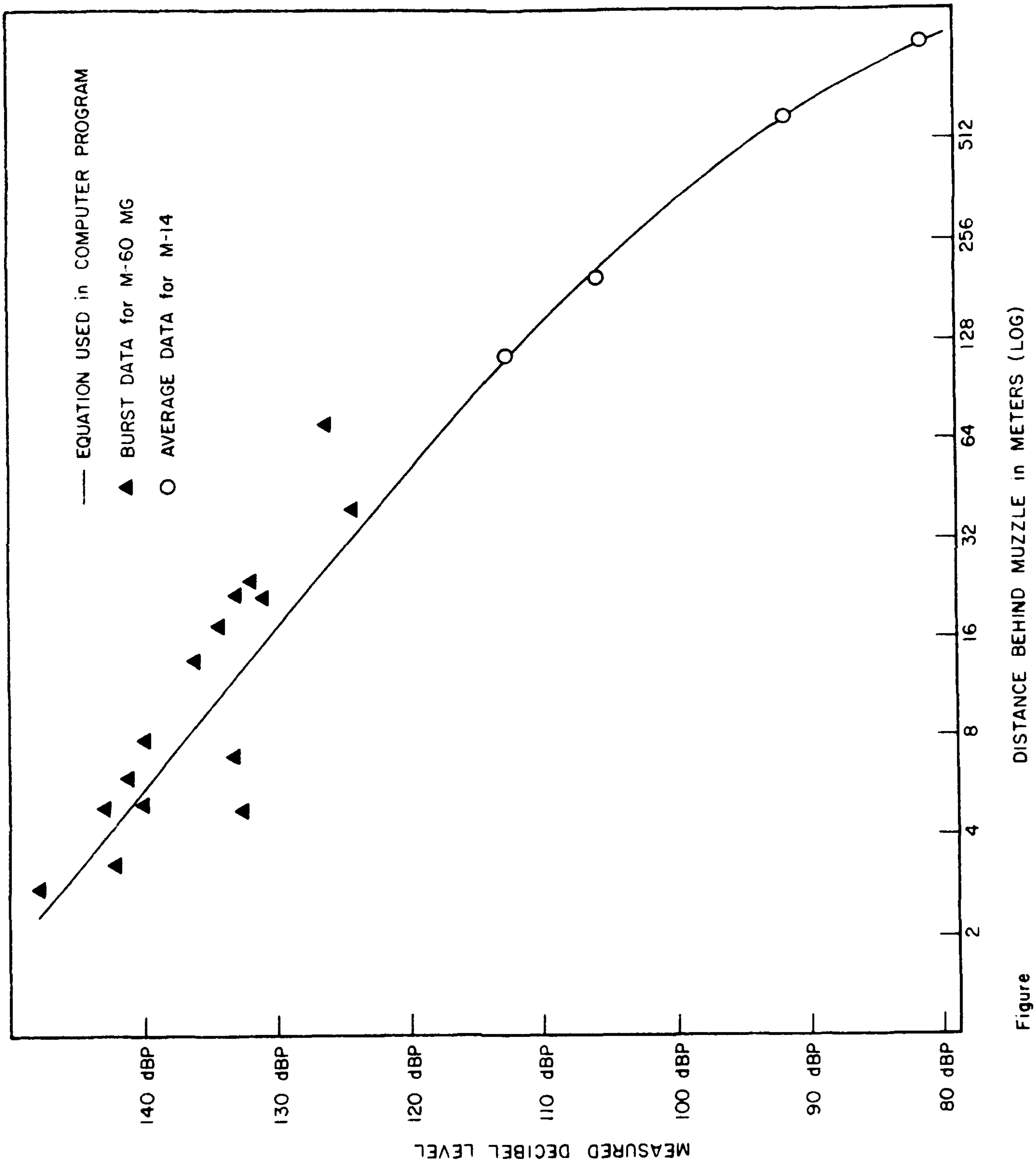
(3) Best fit linear equation:

dBP at distance D = 150.32 - 14.01 ($\log_{10}$ D)
where D is in meters

r = .87

b. 5.56 mm M16. The usual infantry rifle is the M16. On the basis of tube length (39 inches compared to the 22 inch M14) and propellant weight (28.5 grains of WC 844 in the M193 ball compared to 46 grains of WC 846 in the 7.62 mm M80 ball ammunition, Reference 1, Appendix A), one would expect the M14 to be noisier. In fact, the higher chamber pressure and muzzle velocity of the M16 appears to be cancelling out the expected difference. Based on three pieces of evidence, a decision was made to equate the M16 and M14 noise levels:

(1) In an earlier Army procedure for assessing small arms noise (Reference 5, Appendix A), there was no observable difference between the noise of the M16 and the M60.


EQUATION USED in COMPUTER PROGRAM
BURST DATA for M-60 MG
AVERAGE DATA for M-14
2
4
8
16
32
64
128
256
512
DISTANCE BEHIND MUZZLE in METERS (LOG)
140 dBP
130 dBP
120 dBP
110 dBP
100 dBP
90 dBP
80 dBP
MEASURED DECIBEL LEVEL

Figure

(2) In Garinther and Kryter's close up comparison of several shoulder-fired rifles (Reference 3, Appendix A), the peak sound pressure levels measured at the firer's ear were 154.5 dBP for the M16 and 159.0 dBP for the M14. When one corrects for the difference in distance between the firer's ear and the muzzles of the two rifles (assuming a difference of 6 dB per doubling of distance), the M14 would be expected to be 5 dB noisier based on geometry alone.

(3) In Johnson's study (Reference 10, Appendix A), the distance to the 140 dBP contour was 8 meters behind the M60 and 7.5 meters behind the M16. When corrected to equal distances, this difference is less than a dB.

c. .30 Caliber Military Weapons. Although the noise level of US Army .30 caliber weapons is largely an academic question in today's Army, there may be some cases when the subject might be addressed (e.g., an environmental assessment of a range deactivated after World War II). No comparative studies of the .30 caliber weapons could be found, but, based on a comparison of the physical characteristics of these weapons, it was decided to equate them to 7.62 mm weapons. Relevant variables are:

(1) Propellant. The amount of propellant in the .30 caliber (M2) ball ammunition is 50 grains of IMR 4895 compared with 46 grains of WC 846 in the 7.62 mm (M80) ball ammunition (reference 1, Appendix A).

(2) Chamber Pressure. The chamber pressure and velocity is nearly the same (Reference 1, Appendix A).

(3) Tube Length. The 24-inch length of the typical .30 caliber weapon is almost the same as that of the typical 7.62 mm weapon (22 inches). Typical .30 caliber weapons include the M1903A4 sniper's rifle, the Winchester Model 70 rifle, the Browning M1918A2 automatic rifle, the M1 series automatic rifles, the Browning M1919 series machine guns, and M37 tank machine gun.

d. .50 Caliber Machine Guns. The .50 caliber machine guns fire rounds with over four times the propellant as the .30 caliber or 7.62 mm rounds and from barrels which are either 36 inches long (AN-M3 aircraft basic machine gun, Browning AN-M2 automatic machine gun, M85 tank machine gun) or 45 inches long (Browning M2 heavy barrel machine gun). The only comparison between the 7.62 mm and .50 caliber machine guns are the 140 dBP contours published in Reference 9, Appendix A, for the now obsolete M3 and the M60. The 140 dBP contour is 25.6 feet behind the M60 and 37.5 feet behind the M3. Given that the M60 contour is within 3 dB of the predicted value (Pater's equation), it appears that the data were taken with reasonable care and that the comparison is valid. Assuming a 6 dB per doubling attenuation rate, the difference in contours is equal to 3.3 dB. Thus, the decision was made to model all .50 caliber machine guns as being 3 dB noisier than the NATO rifle.

e. Assorted Pistols and Revolvers. From review of some of the available studies of pistol and revolver noise (References 10, 11, 13, 14, Appendix A), it appears that level will vary with type of ammunition, weapon caliber and tube length with the tube length being the most important variable. Because none of the investigators measured with the same equipment or in the same locations relative to the muzzle, a synthesis of these studies was not feasible. Two studies, however, did anchor measures to 7.62 mm weapons (Reference 10, 14, Appendix A), and from these studies, a comparative framework could be developed (Table 3). In this framework, weapons have been classified into one of three caliber groupings and one of three barrel length groupings.

TABLE 3. CORRECTION FACTORS FOR PISTOLS AND REVOLVERS

	Barrel less than 2.5 inch	Barrel between 2.5 and 6 inch	Barrel 6 inch or longer
.22 cal	-5 dB	-13 dB	-15 dB
.32 cal	-2 dB	-10 dB	-12 dB
.375 cal	-2 dB	-10 dB	-12 dB
.38 cal	-2 dB	-10 dB	-12 dB
9 mm	-2 dB	-10 dB	-12 dB
.41 cal	no entry	-5 dB	-7 dB
.44 cal	no entry	-5 dB	-7 dB
.45 cal	no entry	-5 dB	-7 dB

(1) .22 Caliber/Barrel Greater Than 6 Inches. Acton and Forrest (Reference 14, Appendix A) showed the .22 caliber rifle dropping 7 dB with a doubling of distance from 2 to 4 feet. In addition, their noise level for a "long barrel" pistol was later confirmed by Weissler and Kobal (Reference 13, Appendix A) with a 6-inch barrel, .22 caliber revolver. Using the 7 dB attenuation rate to adjust to 3 feet (distance of Acton and Forrest's 7.62 mm rifle measurement) resulted in an estimate of the pistol being 15 dB less than the NATO rifle.

(2) .22 Caliber/Barrel Less Than 2.5 Inches. Acton and Forrest reported a 10 dB difference between the long and short barrel .22 caliber pistols. Although Acton and Forrest do not report barrel length, the difference is so large that it has been assumed that the barrel was less than 2.5 inches. Thus, the short barrel has been estimated as being 5 dB less than the NATO rifle.

(3) .32 - .38 Caliber/Barrel Less Than 2.5 Inches. Johnson (Reference 10, Appendix A) reported the location of the 140 dB peak contour to the rear of the M60, M1911A1 .45 caliber pistol, the .38 caliber pistol with 4 inch barrel and the .38 caliber pistol with 2.5 inch barrel. Johnson assumed an attenuation of 6 dB per doubling of distance. From Johnson's Table E-1, the contour was 6.1 to 9.75 meters behind the short barrel pistol compared to 8 meters behind the M60. Undoubtedly, the 6.1 meter contour was with the most common wadcutter ammunition and it has been taken as the reference value. The calculated difference puts this weapon at 2 dB less than the NATO rifle.

(4) .32 - .38 Caliber/Barrel Between 2.5 and 6 Inches. Johnson's 4 inch barrel, .38 caliber pistol firing wadcutter ammunition, showed an 140 dBP contour at 2.4 meters to the rear. When adjusted for the differences in distance, this leaves an estimate of 10 dB less than the M60.

(5) .41 - .45 Caliber/Barrel Between 2.5 and 6 Inches. With the standard Army M1911A1's 5-inch barrel, Johnson found the 140 dBP contour to be at 4.5 meters to the rear. When adjusted for the differences in distance, this leaves a 5 dB difference from the M60.

(6) Other Entries. Other cells in Table 3 are estimates. The short barrel .45 caliber pistol cell is blank because there are no such weapons. The shortest weapon in this category is the Charter Arms Bulldog .44 Special with a 3-inch barrel.

f. .22 Caliber Rifle. Acton and Forrest reported the .22 caliber rifle to generate 139 dBP at 2 feet. This puts it at 26 dB below the NATO rifle.

g. Shotguns. Johnson (reference 10, Appendix A) reported the 140 dBP contour at 6.1 meters to the rear of the 12 gage shotgun, thus making it 2 dB below the NATO rifle. Although they did not report the weapon, it is most likely that it was either the M12 or Model 1200 Winchester riot-type 12 gage shotgun with a 20-inch barrel. In contrast, Weissler and Kobal (Reference 13, Appendix A) reported a level at 2.2 meters of only 1 dB above a 9 mm, 4-inch barrel pistol (thus making it 9 dB below the NATO rifle by Table 3). Weissler and Kobal's barrel was 30 inches. Since the primary concern in the current technical guide is Army weaponry, the higher estimate has been adopted.

h. Submachine Guns. Submachine guns are characterized by barrels which are longer than pistols and shorter than rifles. Table 4 gives the barrel lengths for some of the common non-Soviet submachine guns.

TABLE 4. COMMON SUBMACHINE GUNS

Country of Orgin	Type	Barrel Length (inches)
Britain	Sterling L2A3 9 mm	7.8
Denmark	Madsen Model 80 9 mm	7.8
Australia	F1 - 9 mm	8.0
Sweden	Carl Gustav Model 48 9 mm	8.0
USA	M3A1 .45 caliber	8.0
Israel	UZI 9 mm	10.2
Switzerland	Rexine-Favor 9mm	10.75

The only comparative measurements are from a study by Sachs (Reference 11, Appendix A) for an unknown model of 9 mm submachine gun at 9 feet. It was 10 dB below a 12 gage shotgun at the same distance. Assuming that Sachs measured the short barrel shotgun, it was decided to model the submachine gun as 12 dB below the NATO rifle (same as the long barrel 9 mm pistol in Table 3).

i. 25 mm Chain Gun. According to a contractor report (Reference 7, Appendix A), the 25 mm chain gun on the new Infantry Fighting Vehicle puts out 174 dBP at 2 meters to the side of the muzzle. The 7.62 mm weapon puts out 156 dBP at the same azimuth and distance, a difference of 18 dB.

j. 20 mm Weapons. In a comparison test made by the Seventh Army Training Command Environmental Office of the 20 mm weapon on the German Marder (Hispana Suiza 30 gun, 20 mm, mounted on the HS 30 vehicle) with the 25 mm Chain Gun (Reference 8, Appendix A), the level at 10 meters, 90 degrees azimuth, was 7 dB (C-weighted) less than 20 mm weapon. Although there are problems with this study, the estimate seems reasonable (11 dB greater than the NATO rifle).

k. 30 mm XM230E1 Hughes Chain Gun. According to a contour provided by a representative of the General Electric Company (Figures B-1 and B-2, Appendix B), the 30 mm round generates 2 pounds per square inch (177 dBP) at 7 feet to the side of the muzzle, thus making it 3 dB more intense than the 25 mm Chain Gun or 21 dB more than NATO rifle.

2-3. SUMMARY. The adjustments decided upon are as follows:

TABLE 5. COMPARISON BETWEEN NOISE OF THE M14 AND OTHER WEAPONS

Weapons	Adjustment dB
30 mm Chain Gun	+21
25 mm Chain Gun	+18
20 mm (Hispana Suiza 30, M139, M197 Vulcan, M61 Vulcan, M195, M168)	+11
.50 caliber Machine Guns	+ 3
7.62 mm rifles or machine guns; M16, .30 caliber rifles and machine guns	0
Shotguns, .32, .375 .38 or 9 mm pistols with barrels less than 2.5 inches	- 2
.45 caliber weapons with barrels less than 6 inches	- 5
.45 caliber pistols or revolvers with barrels between 6 and 8 inches	- 7
.32, .375, .38 or 9 mm pistols with barrels 6 inches or longer including submachine guns	-12
.22 caliber pistols or revolvers with barrels between 2.5 and 6 inches	-13
.22 caliber pistols or revolvers with barrels of 6 inches or more	-15
.22 caliber rifles	-26

APPENDIX A

REFERENCES

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13. Pearl S. Weissler and Michael T. Kobal, "Noise of Police Firearms," Journal of Acoustical Society of America, 56(5), 1974, 1515-1522.

14. W. I. Acton and M. R. Forrest, "Hearing Hazard from Small-Bore Weapons," Journal of Acoustical Society of America 44, 1968, 817-8118.

APPENDIX B

BLAST PRESSURE MAP

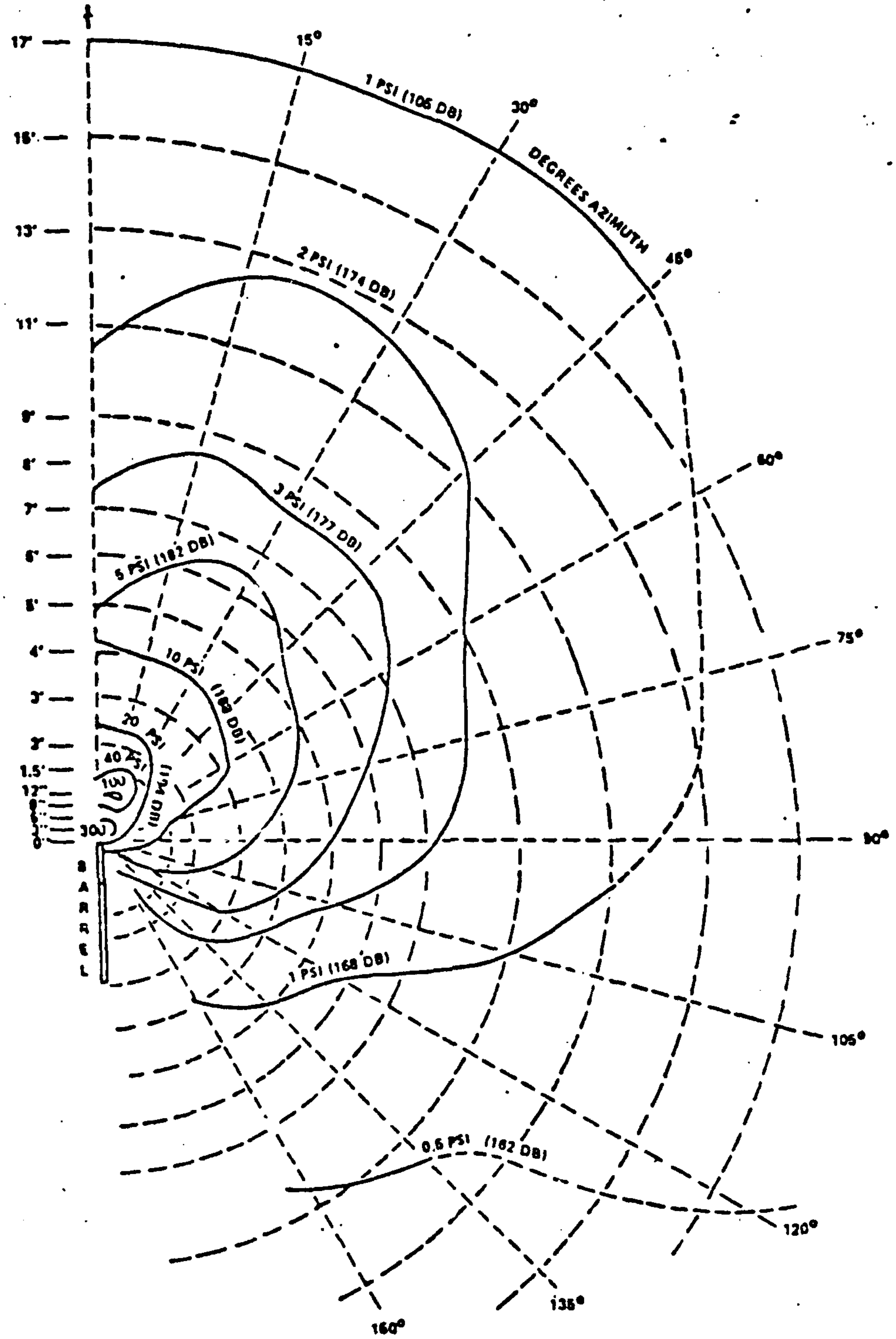

Figure B-1. CAS 30 mm T.P. Round

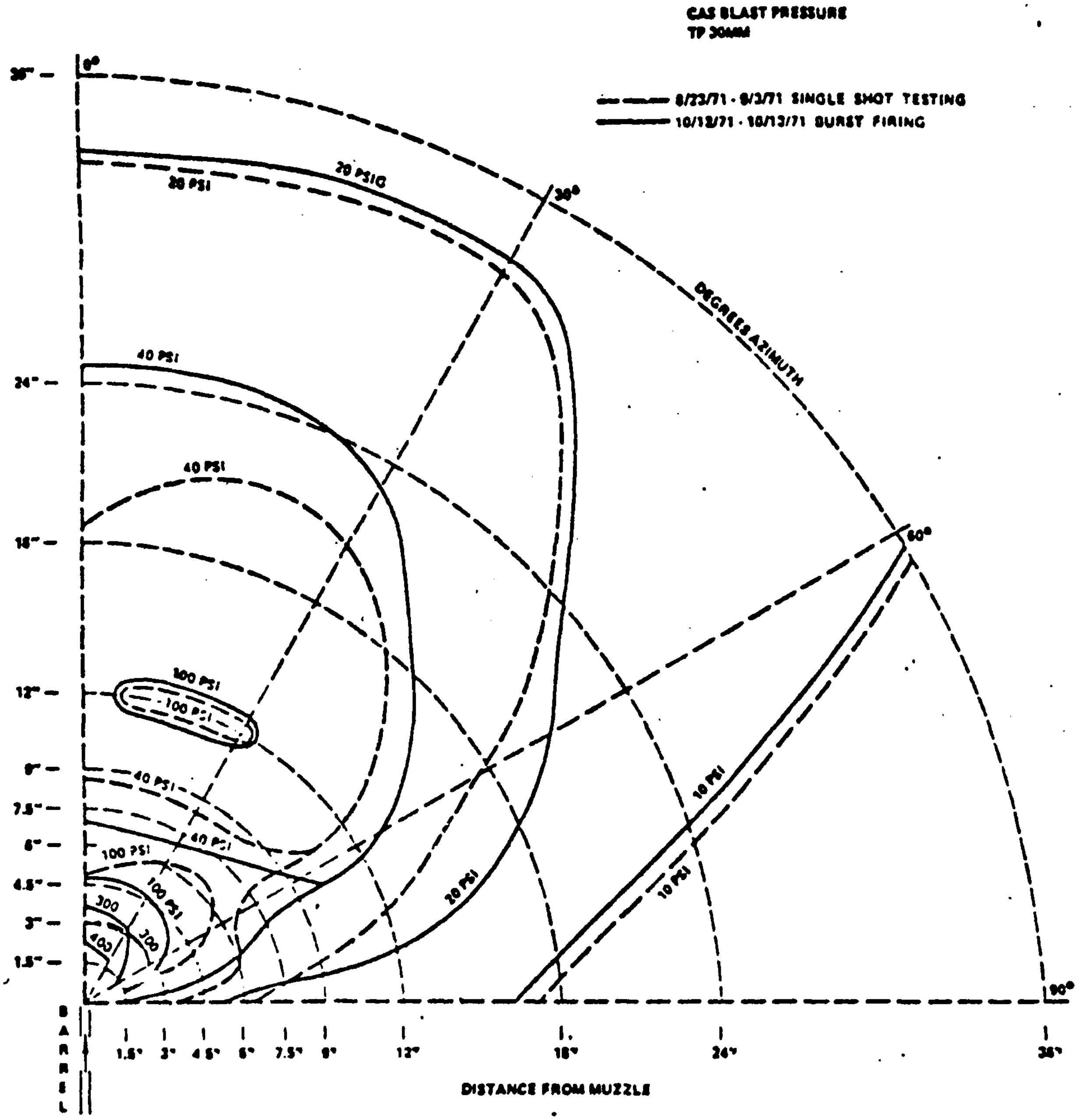

Figure B-2. CAS 30 mm T.P. Round