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USAFOEHL REPORT

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**Impulse Noise Level Measurements in  
Defensive Fighting Position Shelters, AF  
Weapons Laboratory, Kirtland AFB NM**

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<p>The measurement of impulse noise levels produced by the firing of weapons in two designs of the Defensive Fighting Position Shelter was performed. One of the designs is referred to as the U.S. Air Forces in Europe design; the other, the Air Force Weapons Laboratory design. The firing of the following weapons in each shelter was measured: M-16, M-60, MK-19, and M-2. The purpose of the test was to evaluate whether exposures to weapons fire under these conditions are hazardous and, if so, what hearing protection, limitation in number of rounds fired, or both would be required to protect the hearing of those exposed. Double or single hearing protection is recommended under all firing conditions, and is dependent on the type of weapon used and number of rounds fired per day.</p>			
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## I. INTRODUCTION

A. Purpose: This report provides the results of the analysis of impulse noise data collected during the firing of weapons inside two different designs of the Two Man Defensive Fighting Position Shelter (DFP). The tests were conducted at Kirtland AFB NM on 5 Aug 1987. The survey was requested by the Air Force Weapons Laboratory Civil Engineering Research Operations Branch (AFWL/NTE) to determine the health effects of noise on personnel firing weapons from inside the shelters.

B. Problem: Two shelter designs were being evaluated by the AFWL. One design is referred to as the USAFE design (DFP-USAFE), the other as the AFWL design (DFP-AFWL). Training will be performed in the shelters using live ammunition, creating the potential for hearing loss if the proper protective measures are not taken (i.e., wearing personal hearing protection, limiting the number of rounds fired, etc.).

C. Scope: The results of measurements of the peak pressure and duration taken inside each of the shelter designs using a microphone at the position of the ear of the person firing each of four different weapons are reported. Recommendations are made on the proper hearing protection to use during training with the weapons tested.

## II. DISCUSSION

A. Methodology. Each of the weapons, except the M-16, was fired from the prototype shelters on 5 Aug 1987. Two microphones were placed inside the shelter during firing. One was positioned within one foot of the operator's ear, oriented so the sound from the weapon struck the microphone with grazing incidence. The second microphone was positioned in the center of the shelter to serve as a backup measurement and to determine if exposure to a second person in the shelter was higher than the operator's exposure. The signals were fed to a Nicolet Model 4094B Digital Oscilloscope for recording and storage on floppy disks. The signals were also recorded on a tape recorder as a backup to the digital signals. A 114 decibel (dB), 1,000 Hertz (Hz) acoustical calibration signal was applied to both microphones before and after the survey. A complete list of equipment is given at Appendix A. The data recorded on the floppy disks on 5 Aug 87 was then analyzed after return to the USAFCEHL. The M-16 was not available on 5 Aug 1987 for testing. Personnel from the local bioenvironmental engineering office performed testing on the M-16 at a later date and provided us the results. No pulse durations were measured for the M-16, but since the peak levels are low this is not particularly significant.

B. Standards. Air Force policy on exposures to impulse noise is outlined in AFR 161-35, Hazardous Noise Exposure. No unprotected exposure to levels of more than 140 dB peak sound pressure level is permitted. Exposure to levels in excess of 160 dB requires the use of double hearing protection (plugs and muffs). A new draft noise standard, AFOSH Standard 161-YY, Hazardous Noise Program, is under consideration by HQ USAF/SGPA and provides criteria consistent with the present standard. However, this draft standard is more definitive, since peak levels as well as pulse durations are used in the

selection of hearing protection. The applicable portion of this draft standard is outlined in Appendix B. Comparison will also be made to this standard.

C. Results. A summary of the values measured is shown in Table 1. The average values for the peak pressures in kilopascals (kPa) and the equivalent peak pressure levels in decibels, recorded for each of the weapons in both shelters, are shown. The maximum values actually measured are listed also. The average value plus two standard deviations were calculated and are the values used for comparison to the standard and to provide recommendations. Representative pressure versus time curves are shown in Appendix C, Figures 1 through 6, for each of the three weapons in each of the two shelter designs measured by the USAFOEHL. These pressure-time curves are, of course, not available for the M-16.

D. Observations. The hearing protection required by AFR 161-35 is a function of both the level of the impulse and its B-duration, as well as the number of rounds fired in a single day. Above 140 dB peak sound pressure level AFR 161-35, Hazardous Noise Exposure, requires the use of single hearing protection (plugs or muffs) regardless of the duration of exposure. Above 160 dB the use of double hearing protection (plugs and muffs) is required. Applying the criteria from paragraph 21.c. and Attachment 22 of AFR 161-35 results in the protection criteria for the DFPs outlined in Table 2. The hearing protection which would be required by the draft AFOSH Standard 161-YY is shown in Table 3. Again, exposures above 140 dB require at least single protection. However, the pulse duration plays a greater role in determining the required protection.

### III. CONCLUSIONS

A. The noise produced by the weapons tested in the two shelters is hazardous to hearing and hearing protection is required to protect exposed personnel from hearing loss.

B. The protection and firing limitations outlined in Table 2 will protect the hearing of persons firing the weapons listed from the two DFP shelters. The protection outlined in Table 3 would be required if the draft AFOSH Standard is adopted.

### IV. RECOMMENDATION

The hearing protection outlined in Table 2 should be worn when the number of rounds to be fired in a day is as indicated for the appropriate weapons. Should the draft AFOSH Standard 161-YY, Hazardous Noise Program, be adopted, the protection outlined in Table 3 may be used.

Table 1. Peak Pressures and Peak Pressure Levels Measured During Test Firing from the Defensive Fighting Position Shelters, 5 August 1987.

SHELTER Weapon	Peak Pressure (kilopascals)		Peak Pressure Level (decibels)		B-duration (milliseconds)		Points Averaged
	Average measured	Average plus two standard deviations	Average measured	Average plus two standard deviations	Average measured	Average plus two standard deviations	
	(Maximum Measured)	(Standard deviation)	(Maximum measured)	(Maximum measured)	(Maximum measured)	(Standard deviation)	
<u>DFP-USAFE</u>							
M-16 *	0.251 (0.310)	0.419 (0.084)	142 (144)	146	N/A	N/A	2
M-60	2.13 (2.95)	3.07 (0.47)	161 (163)	164	76.2 (98.2)	101 (12.5)	17
MK-19	3.43 (4.38)	4.38 (0.48)	165 (167)	167	83.6 (90.0)	100 (8.4)	8
M-2	0.386 (0.594)	0.575 (0.094)	146 (150)	149	118 (144)	152 (17.3)	9
<u>DFP-AFWL</u>							
M-16 *	0.154 (0.159)	0.169 (0.0075)	138 (138)	139	N/A	N/A	2
M-60	1.08 (1.12)	1.22 (0.071)	155 (155)	156	55.2 (58.9)	61.4 (3.1)	5
MK-19	2.87 (3.11)	3.25 (0.19)	163 (164)	164	77.2 (86.0)	91.0 (6.9)	4
M-2	0.525 (0.545)	0.567 (0.021)	148 (149)	149	77.1 (78.3)	79.3 (1.1)	3

\* - Measurements made using GenRad Model 1988 Sound Level Meter.

Table 2. Personal Hearing Protection Criteria for Weapons Fire in Defensive Fighting Position Shelters Required by AFR 161-35.

<u>Shelter</u> Weapon	Protection Required			
		N - None	S - Single (Plugs <u>or</u> muffs)	D - Double (Plugs <u>and</u> muffs)
	Rounds Fired per Day	5	100	1,000
<u>DFP-USAFE</u>				
M-16		N *	S	S
M-60		S	D	D
MK-19		D	D	D
M-2		S	S	S
<u>DFP-AFWL</u>				
M-16		N *	S	S
M-60		S	S	D
MK-19		S	D	D
M-2		S	S	S

\* - Technically no protection is required under these conditions, however, it is always best to wear at least single protection for these types of exposure.

Table 3. Personal Hearing Protection Criteria for Weapons Fire in Defensive Fighting Position Shelters Proposed by Draft AFOSH Standard 161-YY.

<u>Shelter Weapon</u>	<u>Protection Required</u>			
	N - None S - Single (Plugs <u>or</u> muffs) D - Double (Plugs <u>and</u> muffs)			
	<u>Rounds Fired per Day</u>	5	100	1,000
<u>DFP-USAFE</u>				
M-16		S	S	S
M-60		S	S	S
MK-19		S	S	D
M-2		S	S	S
<u>DFP-AFWL</u>				
M-16		N *	S	S
M-60		S	S	S
MK-19		S	S	D
M-2		S	S	S

\* - Technically no protection is required under these conditions, however, it is always best to wear at least single protection for these types of exposure.

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**APPENDIX A**  
**Measurement Equipment List**

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## MEASUREMENT EQUIPMENT LIST

<u>Equipment</u>	<u>Manufacturer</u>	<u>Model/Type</u>	<u>Serial Number</u>
Digital Oscilloscope	Nicolet	4094B	88B02987
Tape Recorder	B & K Instruments	7006	1307051
Microphone	B & K Instruments	4136	392527
Microphone Preamplifier	B & K Instruments	2619	594034
Microphone	B & K Instruments	4136	392542
Microphone Preamplifier	B & K Instruments	2619	418488
Microphone Power Supply	B & K Instruments	2804	1338144

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**APPENDIX B**  
**Draft AFOSH Standard 161-YY,**  
**Hazardous Noise Program Impulse Noise Standards**

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## IMPULSE NOISE

1. **Impulse or Impact Exposure Limits.** Unprotected exposures shall not exceed 140 dB peak sound pressure level. Above 140 dB peak sound pressure level the applicable impulse noise limits are determined based on the expected number of exposures per day and the type of hearing protection used. Table A1-1 identifies the required hearing protection curve, shown in Figure A1-1, based on the type of protection and number of daily exposures. The limit for a given protection requirement becomes more restrictive (a lower curve limits exposures) as the number of impulses per day increases. Figure A1-1 shows the peak level versus B-duration curves which limit the allowable exposure based on the type of protection worn. Table A1-2 lists the peak impulse levels produced at the ear by various weapons under non-reverberant conditions (outdoors) for a single shot. These levels should not be used for reverberant conditions (such as indoor firing ranges) and do not include the noise produced by other weapons firing near the shooter.

2. **Impulse Noise Evaluations.** There are two types of measurements to be used in evaluating impulse or impact noise exposures: screening measurements and detailed evaluations.

a. **Screening Measurements.** To determine if levels exceed 140 dB peak sound pressure level, a sound level meter having the capability to measure impulse or impact noise may be used to determine the peak of the impulse. This measurement shall be documented on the DD Form 2214. If measurement shows the levels to exceed 140 dB, the detailed evaluation shall be performed. Levels less than or equal to 140 dB may be evaluated as in para. 3a, with no unprotected exposure allowed above 115 dB(A).

b. **Detailed Evaluations.** Field measurements of impulse and impact noise are sometimes difficult and require special equipment to measure the B-Duration. When peak impulse levels are determined to be above 160 dB consultation with the USAFOEHL should be obtained as described in AFR 161-17, USAF Occupational and Environmental Health Laboratory (OEHL) Services.

Table A1-1. Impulse Noise Personal Protection Selection Criteria.

Maximum Expected Number of Exposures in a Single Day *	Impulse Noise Limit Curve		
	No Protection	Either Plugs Or Muffs	Both Plugs and Muffs
1000	W	X	Y
100	W	Y	Z
5	W	Z	Z **

\* A single exposure consists of either (a) a single pulse for non-repetitive systems (systems producing not more than one impulse per second, such as semi-automatic weapons), or (b) a burst for repetitive systems (systems normally producing more than one impulse per second, such as automatic weapons).

\*\* Higher levels than curve Z are not permitted since other, non-auditory physiological injury may occur.

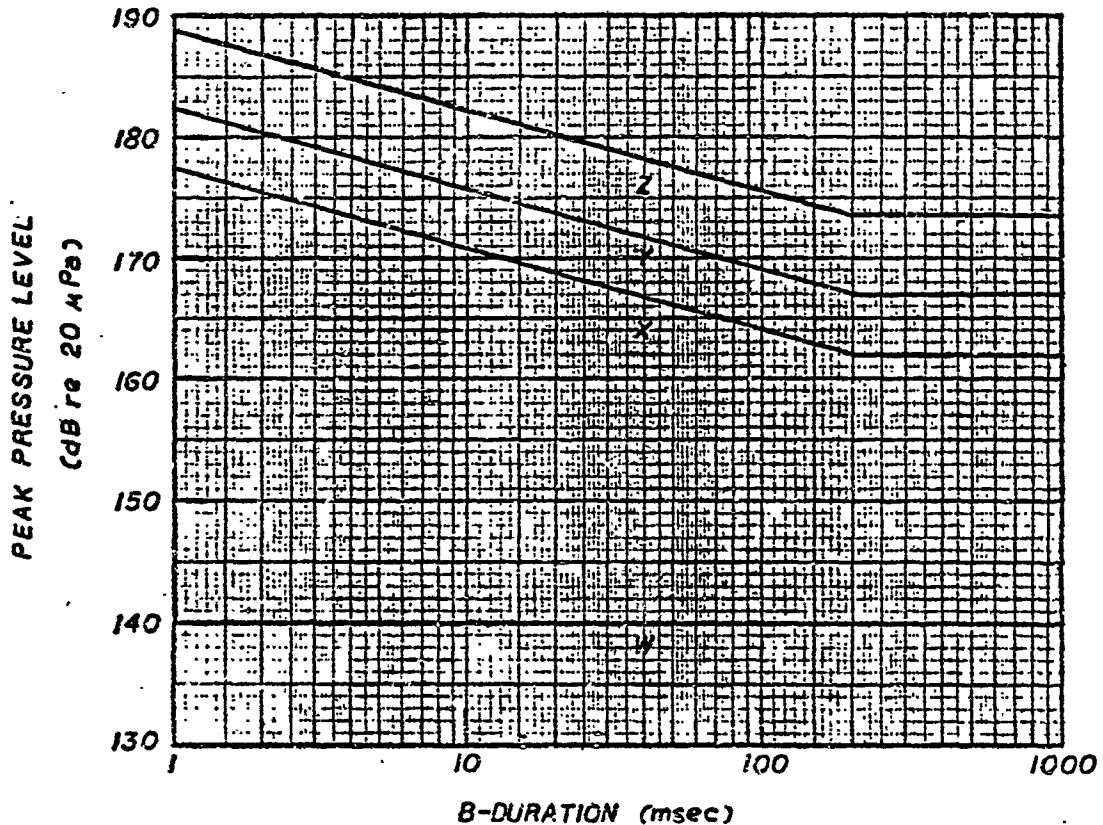
Table A1-2. Impulse Levels for Weapons.

Weapon	Single Fire, Peak Impulse	
	Peak Level (dB)	
M-1, Rifle, .30 caliber	161	
Submachine gun, .45 caliber	160	
M-58, .50 caliber	161	
M-14, (EZ) Rifle	140	
M-16. Rifle, 7.62 mm	160	
90 mm Recoilless Rifle	188	
M-60, Machine Gun, 7.62 mm	161	

Note: Levels measured outdoors at shooter's ear with no other weapons firing.

Figure A1-1. Peak Pressure Level and B-Duration Limits for Impulse Noise

(See Table A1-1 to select curve for safe use. Note: Exposure to levels in excess of limit W requires mandatory hearing protection.)



NOTE: Formulas for plotting the curves are:

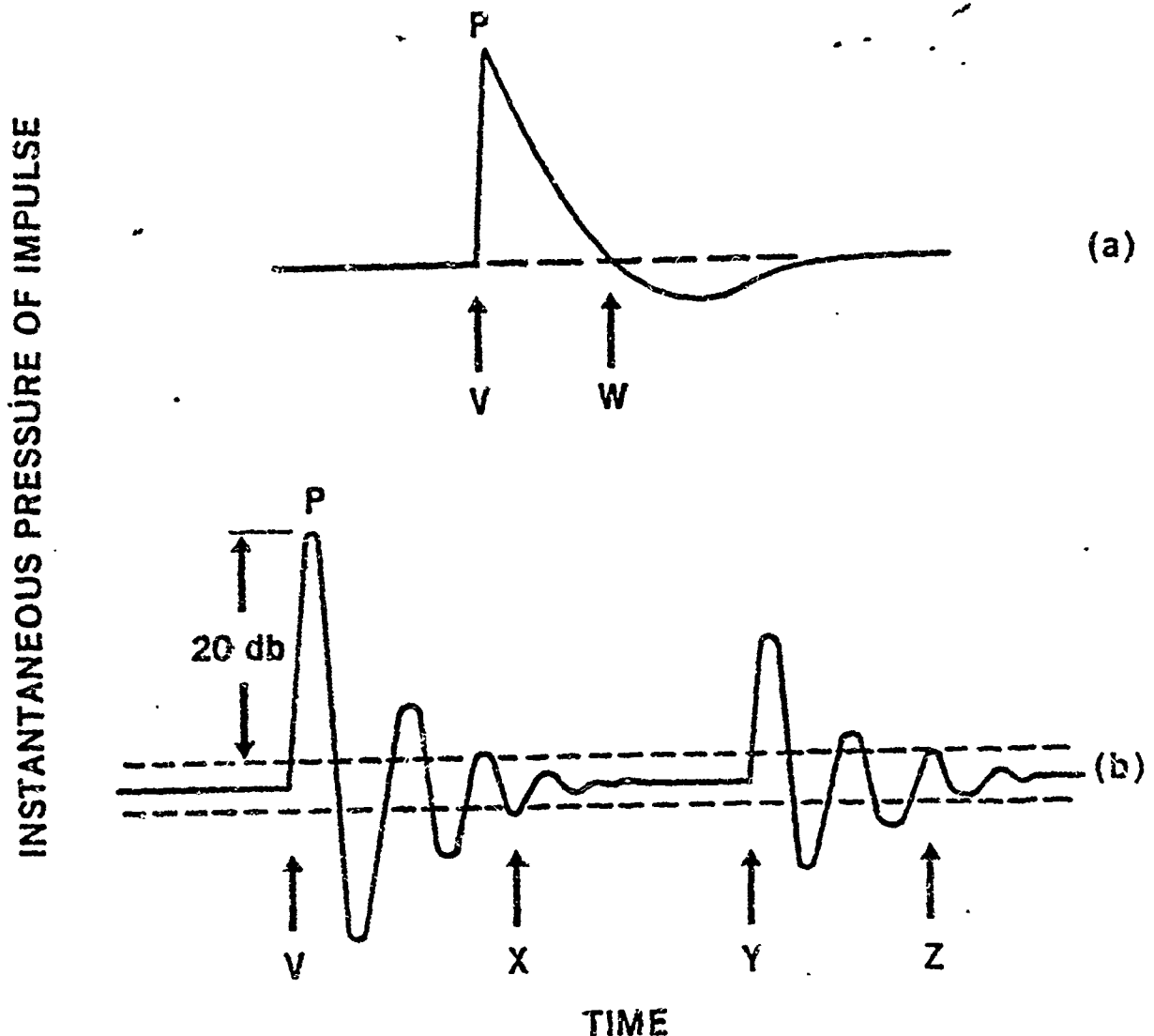
$$PPL_Y = 167 + \{[2 \cdot \log(200/T)] / \log 2\}, \text{ for } T \leq 200 ;$$

$$PPL_Y = 167, \text{ for } T > 200$$

Where:  $PPL_Y$  = Peak Pressure Level of curve Y, in dB,

$T$  = B-duration, in milliseconds.

Curve Z is 6.5 dB above curve Y and curve X is 5 dB below curve Y.



P is the peak pressure level measured at the position of the ear when the individual is not present (if it is possible for the device to be operated without the individual present).

A-duration, the pressure-wave duration, is the time required for the initial or principal wave to reach the peak pressure level and return momentarily to zero. In part (a) of this figure this duration is from point V to point W.

B-duration, the pressure-envelope duration, is the total time the envelope of the pressure fluctuations (both positive and negative) is within 20 dB of the peak pressure level, including reflected waves. In part (b) of this figure the B-duration would be from V to X plus Y to Z.

Figure A1-2. Determination of A-Duration and B-Duration.

**APPENDIX C**  
**Pressure versus Time Waveforms**

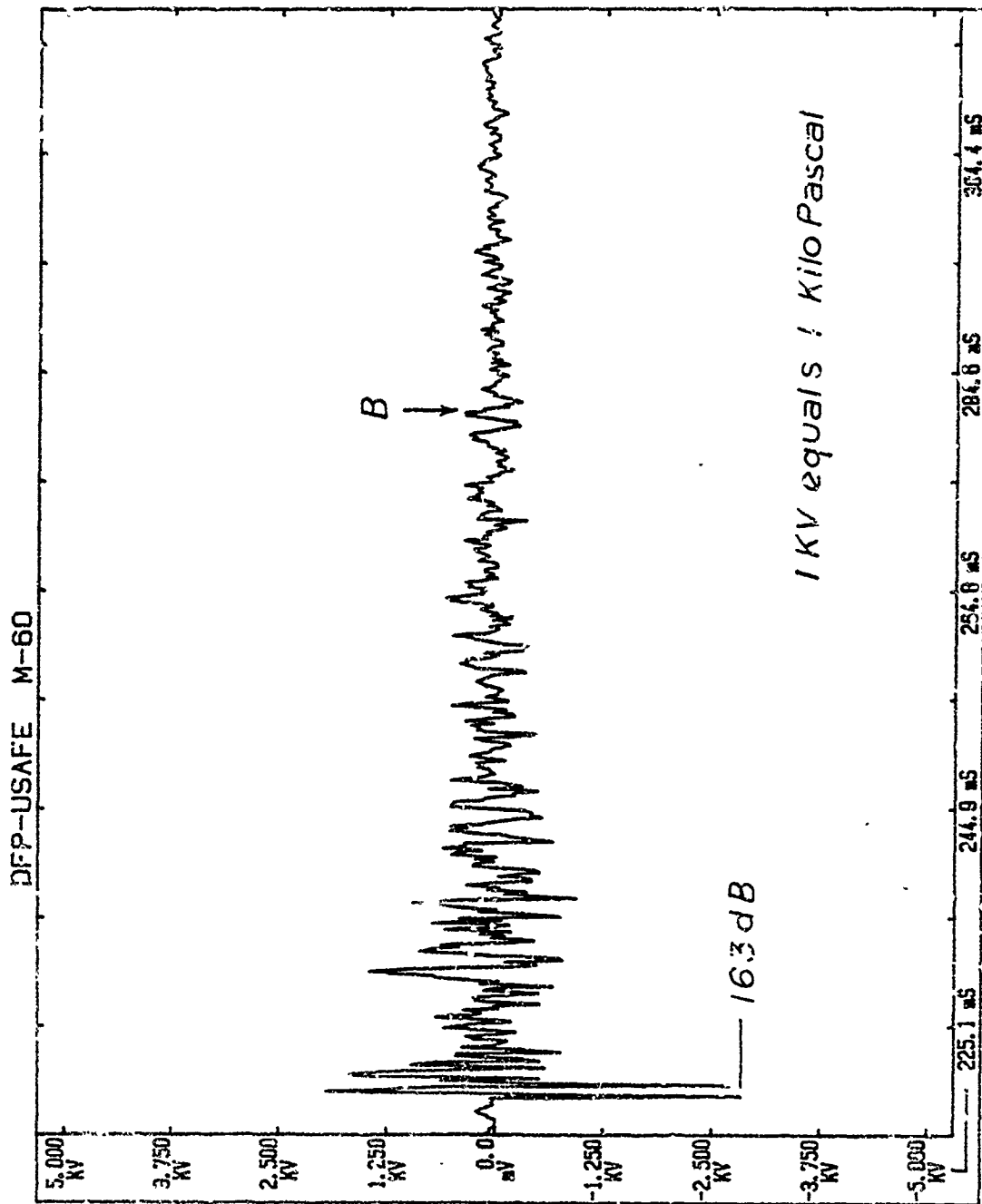


Figure 1. M-60, DFP-USAFE, Pressure Versus Time Waveform, 163 dB Peak, 62.0 ms B-duration

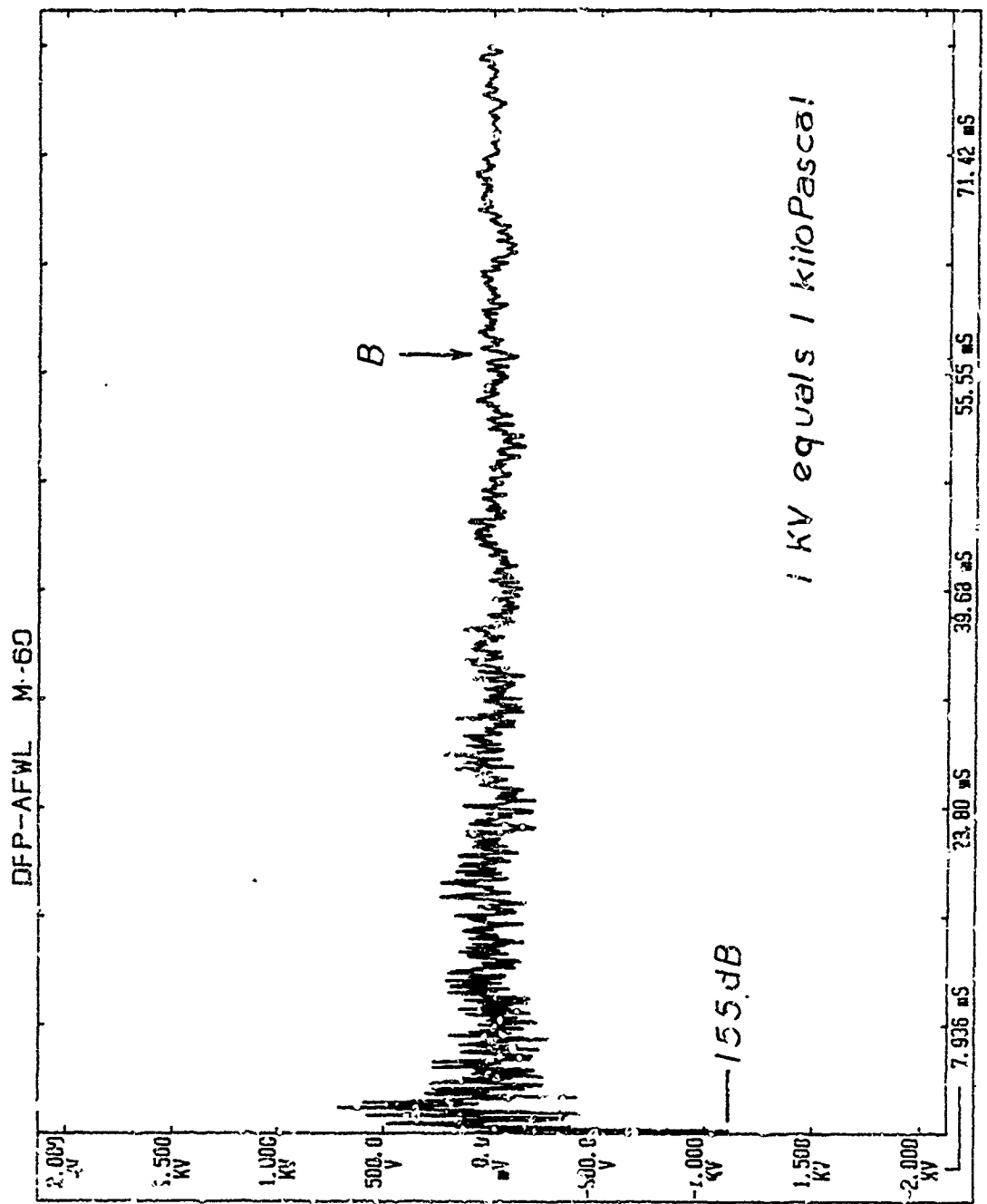


Figure 2. M-60, DFP-AFWL, Pressure Versus Time Waveform, 155 dB Peak, 56.6 ms B-duration

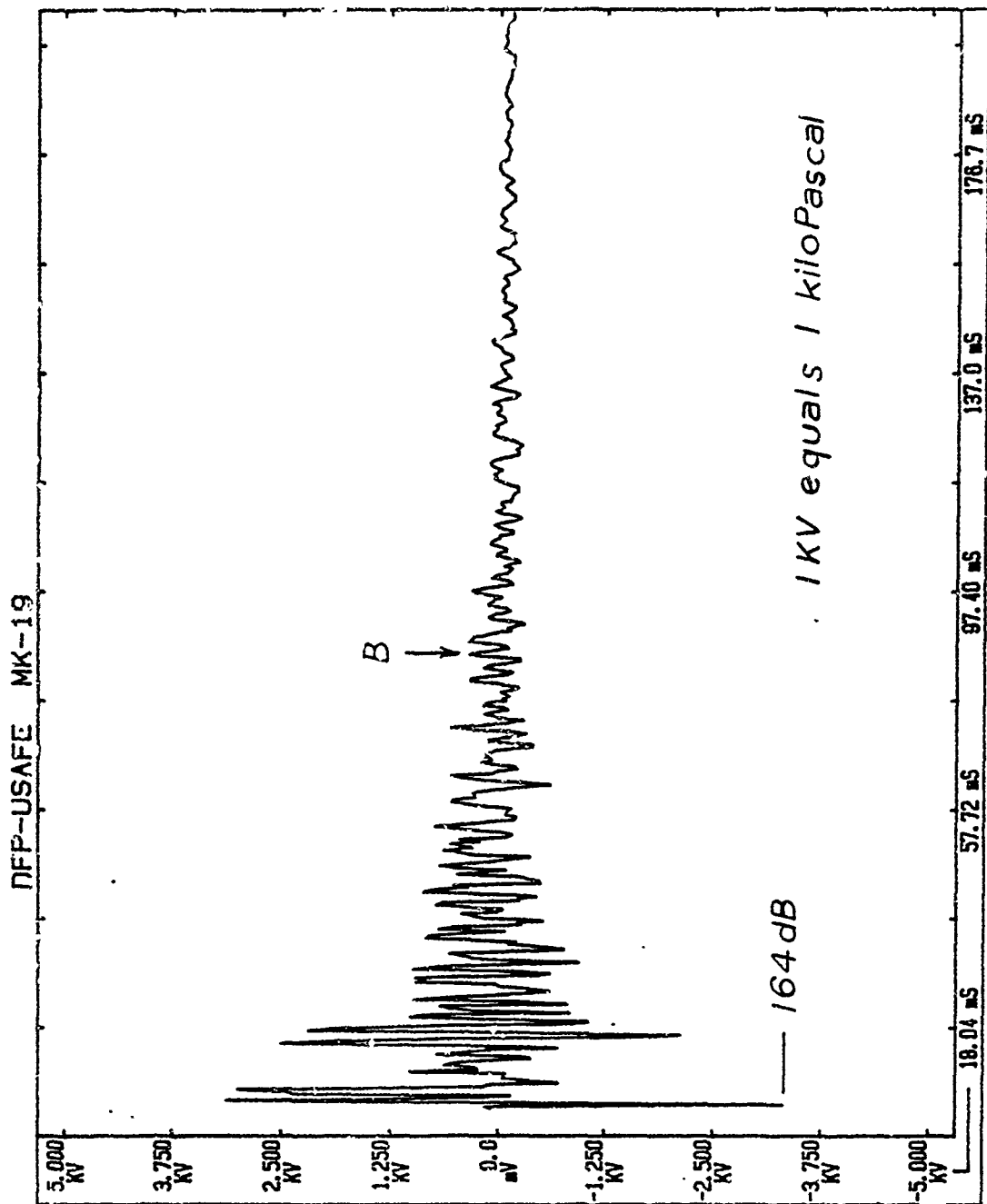


Figure 3. MK-19, DFP-USAFE, Pressure Versus Time Waveform, 164 dB Peak, 85.8 ms B-duration

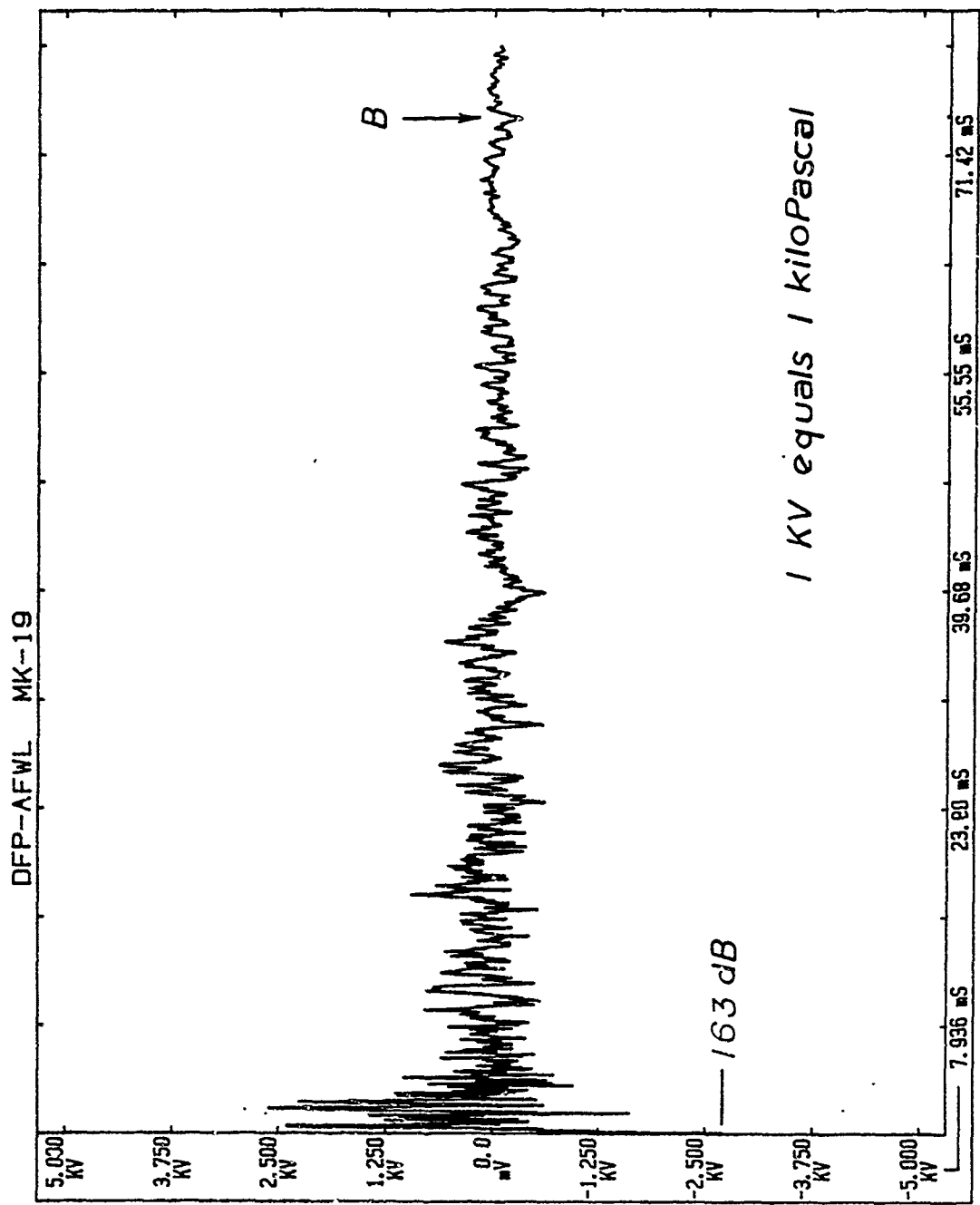


Figure 4. MK-19. DFP-AFWL, Pressure Versus Time Waveform, 163 dB Peak, 74 2 ms B-duration

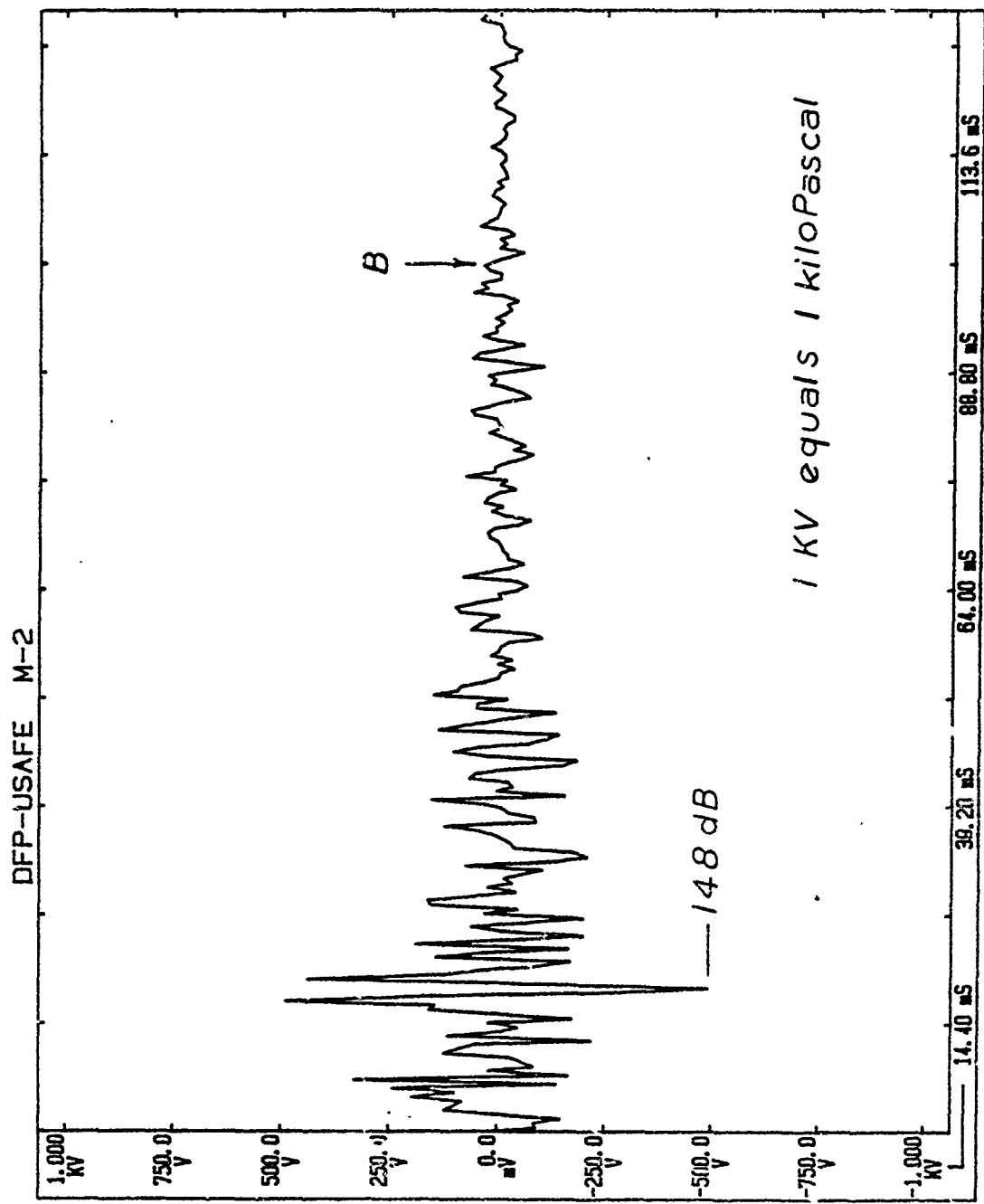


Figure 5. M-2, DFP-USAFE, Pressure Versus Time Waveform, 148 dB Peak, 101 ms B-duration

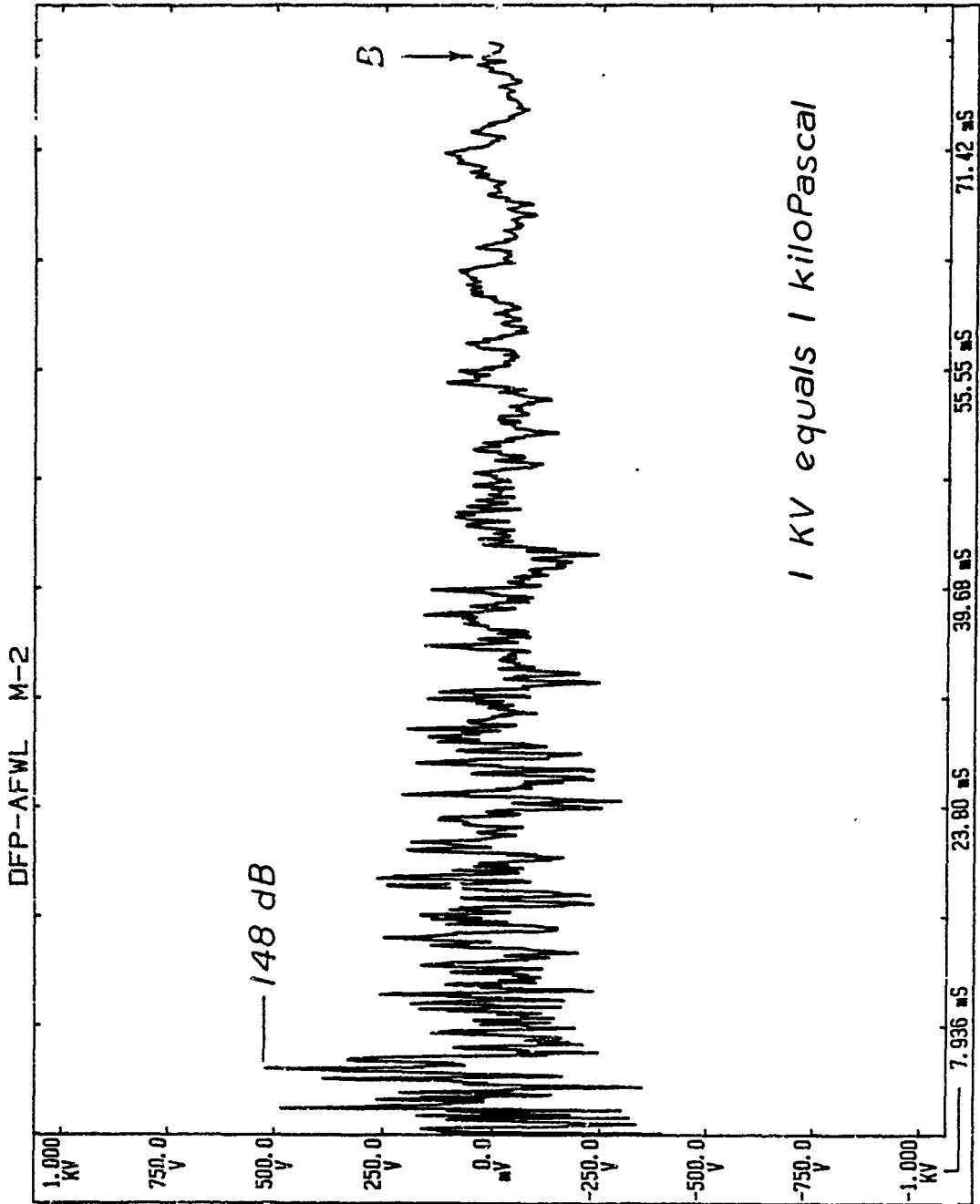


Figure 6. M-2, DFP-AFWL, Pressure Versus Time Waveform, 148 dB Peak, 76.6 ms B-duration

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