



**Actual Effectiveness of Hearing Protection
in High Level Impulse Noise
(Reprint)**

By

**James H. Patterson, Jr.
Ben T. Mozo**

Aircrew Protection Division

and

**Daniel L. Johnson
EG&G Special Projects**

DTIC
ELECTE
JAN 04 1995
S G D

19941230 025

DTIC QUALITY INSPECTED 2

August 1994

Approved for public release; distribution unlimited.

**United States Army Aeromedical Research Laboratory
Fort Rucker, Alabama 36362-0577**

Notice

Qualified requesters

Qualified requesters may obtain copies from the Defense Technical Information Center (DTIC), Cameron Station, Alexandria, Virginia 22314. Orders will be expedited if placed through the librarian or other person designated to request documents from DTIC.

Change of address

Organizations receiving reports from the U.S. Army Aeromedical Research Laboratory on automatic mailing lists should confirm correct address when corresponding about laboratory reports.

Disposition

Destroy this document when it is no longer needed. Do not return it to the originator.

Disclaimer

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation. Citation of trade names in this report does not constitute an official Department of the Army endorsement or approval of the use of such commercial items.

Reviewed:



KEVIN T. MASON
LTC, MC, MFS
Director, Aircrew Protection
Division

Released for publication:



ROGER W. WILEY, O.D., Ph.D.
Chairman, Scientific
Review Committee



DENNIS F. SHANAHAN
Colonel, MC, MFS
Commanding

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
1a. REPORT SECURITY CLASSIFICATION Unclassified		1b. RESTRICTIVE MARKINGS			
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release, distribution unlimited			
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE					
4. PERFORMING ORGANIZATION REPORT NUMBER(S) USAARL Report No. 94-48		5. MONITORING ORGANIZATION REPORT NUMBER(S)			
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Aeromedical Research Laboratory		6b. OFFICE SYMBOL (if applicable) SGRD-UAS-AS	7a. NAME OF MONITORING ORGANIZATION U.S. Army Medical Research, Development, Acquisitions and Logistics Command		
6c. ADDRESS (City, State, and ZIP Code) P.O. Box 620577 Fort Rucker, AL 36362-0577		7b. ADDRESS (City, State, and ZIP Code) Fort Detrick Frederick, MD 21702-5012			
8a. NAME OF FUNDING/SPONSORING ORGANIZATION		8b. OFFICE SYMBOL (if applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER		
8c. ADDRESS (City, State, and ZIP Code)		10. SOURCE OF FUNDING NUMBERS			
		PROGRAM ELEMENT NO. 62787A	PROJECT NO. 30162787A878	TASK NO. I	WORK UNIT ACCESSION NO. 285
11. TITLE (Include Security Classification) Actual effectiveness of hearing protection in high level impulse noise					
12. PERSONAL AUTHOR(S) J. H. Patterson, Jr., B. T. Mozo, and D. L. Johnson					
13a. TYPE OF REPORT		13b. TIME COVERED FROM _____ TO _____	14. DATE OF REPORT (Year, Month, Day) 1994 August		15. PAGE COUNT 8
16. SUPPLEMENTARY NOTATION Reprinted from Noise & Man '93: Noise as a public health problem. Paris, France					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB-GROUP	exposure limits, hearing protection, impulse noise, low frequency attenuation, earplugs		
20	14				
23	04				
19. ABSTRACT (Continue on reverse if necessary and identify by block number) Current exposure limits for high intensity impulse noise contain factors for hearing protection which are based on very limited data. Recent studies in the U.S. and in France have provided new insights into the protection afforded by hearing protective devices. For impulses with an A-duration of approximately 3.0 ms, protection was found to be adequate for peak pressures up to 190 dB SPL for 6 impulses and 187 dB for 100 impulses. Protection was found to be adequate for 6 impulses with an A-duration of approximately 0.8 ms up to 196 dB SPL. For this A-duration, protection was adequate for 12 impulses up to 190 dB SPL and for 50 and 100 impulses at 187 dB SPL. The hearing protectors used in these studies were earmuffs with perforations in the cushions which provided essentially no attenuation below 500 Hz. In a series of French studies, hearing protection was found to be adequate for impulses produced by a variety of weapons with peak pressures ranging from 165 dB SPL to 180 dB SPL. These included small arms with A-durations less than 1.0 ms, artillery with A-durations of approximately 3.0 ms and other weapons with durations between these extremes. A variety of insert hearing protectors (earplugs) was used in (Continued on next page)					
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION Unclassified		
22a. NAME OF RESPONSIBLE INDIVIDUAL Chief, Science Support Center			22b. TELEPHONE (Include Area Code) 205-255-6907	22c. OFFICE SYMBOL SGRD-UAX-SI	

19. Abstract (continued)

these studies. All had perforations which resulted in poor low frequency attenuation. In both sets of studies, conventional attenuation rating schemes greatly underestimated the actual protection afforded by the hearing protective devices. Direct measurements of the pressures under the earmuff showed these peak levels can be as high as 182 dB SPL without significant effects on hearing.

**ACTUAL EFFECTIVENESS OF HEARING PROTECTION
IN HIGH LEVEL IMPULSE NOISE**

PATTERSON, James H., Jr. and MOZO, Ben T.
U.S. Army Aeromedical Research Laboratory
P.O. Box 620577
Ft. Rucker, Alabama USA 36362-0577

JOHNSON, Daniel L.
EG&G Special Projects
Albuquerque, New Mexico USA 87119-9024

ABSTRACT

Current exposure limits for high intensity impulse noise contain factors for hearing protection which are based on very limited data. Recent studies in the U.S. and in France have provided new insights into the protection afforded by hearing protective devices. For impulses with an A-duration of approximately 3.0 ms, protection was found to be adequate for peak pressures up to 190 dB SPL for 6 impulses and 187 dB for 100 impulses. Protection was found to be adequate for 6 impulses with an A-duration of approximately 0.8 ms up to 196 dB SPL. For this A-duration, protection was adequate for 12 impulses up to 190 dB SPL and for 50 and 100 impulses at 187 dB SPL. The hearing protectors used in these studies were earmuffs with perforations in the cushions which provided essentially no attenuation below 500 Hz. In a series of French studies, hearing protection was found to be adequate for impulses produced by a variety of weapons with peak pressures ranging from 165 dB SPL to 180 dB SPL. These included small arms with A-durations less than 1.0 ms, artillery with A-durations of approximately 3.0 ms, and other weapons with durations between these extremes. A variety of insert hearing protectors (earplugs) was used in these studies. All had perforations which resulted in poor low frequency attenuation. In both sets of studies, conventional attenuation rating schemes greatly underestimated the actual protection afforded by the hearing protective devices. Direct measurements of the pressures under the earmuff showed these peak levels can be as high as 182 dB SPL without significant effects on hearing.

**Efficacité Réelle des Protecteurs Auditifs
Pour des Expositions à des Bruits Impulsionnels
de Niveau de Crête élevé**

RÉSUMÉ

Les critères d'exposition usuels aux bruits impulsionnels de fort niveau permettent de tenir compte de la protection auditive utilisée mais seulement à partir de résultats très limités. Des

Accession For	
NTIS CRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution /	
Availability Codes	
Dist	Avail and/or Special
A-1	

études récentes réalisées aux Etats-Unis et en France ont apporté de nouvelles indications quant à la protection effective fournie par les protecteurs auditifs. Pour des impulsions d'une durée de première phase positive (durée A) d'environ 3 ms, la protection employée était adéquate pour des niveaux de surpression de crête allant jusqu'à 190 dB SPL pour 6 coups et jusqu'à 187 dB SPL pour 100 coups. La protection était également adéquate pour 6 coups d'une durée A d'environ 0,8 ms et de 196 SPL de surpression de crête. Pour la même durée, la protection était adéquate pour 12 coups jusqu'à 190 dB SPL et pour 50 et 100 coups jusqu'à 187 dB SPL. Les protecteurs auditifs utilisés dans ces études étaient des serre-tête dont les coussinets avaient été perforés et qui, de ce fait, n'apportaient pas d'atténuation pour les fréquences inférieures à 500 Hz. Dans une série d'études réalisées en France, la protection auditive était adéquate pour des expositions à des bruits impulsionnels produits par des armes et dont les surpressions de crête allaient de 165 à 180 dB SPL. Ces bruits correspondaient soit à ceux produits par des armes légères (durée A inférieure à 0,1 ms), soit à ceux produits par des pièces d'artillerie (durée A d'environ 3 ms), ainsi qu'à ceux d'autres armes de durées A intermédiaires. Dans ces études, les protecteurs auditifs utilisés étaient des bouchons d'oreilles de différents types qui comportaient tous des perforations induisant une faible atténuation aux basses fréquences. Dans ces deux types d'études, l'atténuation des protecteurs auditifs mesurée de façon conventionnelle sous-estimait la protection effective apportée par les protecteurs. Des mesures directes de pression réalisées sous la coquille des serre-tête ont montré que les niveaux de crête pouvaient atteindre 182 dB SPL sans que l'on observe d'effet significatif sur l'audition des sujets.

Introduction: In 1968, CHABA published a "Proposed damage risk criterion for impulse noise (gunfire)" derived from Coles et al. (1968). This criterion was based on data from exposure of unprotected humans and made no provision for extending the limit when hearing protection is used. Three basic approaches have been used to resolve this shortcoming. The first was to estimate the protection and simply raise the unprotected exposure limit by the amount of the protection. The second approach was to expose people with protection to an impulse noise and look for effects on their hearing. Finally, the impulse noise penetrating the protector can be measured and the unprotected limits applied to this measured pressure-time signature.

Fixed protective values: The development of the military standard, which establishes the exposure limits for military equipment in the United States, is an example of the first approach. Based on the results of a study of exposure to shoulder-fired antiarmor weapon noise with earplugs, Garinther and Hodge (1971) concluded that hearing protectors provided 29 dB of protection. This amount of protection was incorporated into MIL-STD-1474 to establish our current exposure limits by raising the CHABA (1968) criterion by this amount (Garinther and Hodge, 1981). Thus, twenty-nine dB of protection is accorded to any protector regardless of its attenuation characteristic. In Germany, Pfander (1975) developed an impulse noise exposure limit using 25 dB as the amount of protection. The protected limit is simply the unprotected limit raised by 25 dB.

Direct determination studies: In the 1970s, the impulse noise produced by new heavy weapons became a matter of concern to the U.S. Army because it exceeded the protected exposure limits. This led to studies designed to determine whether then current hearing

protection was adequate for these weapons. Patterson et al., (1985) showed that foam earplugs provided adequate protection for artillery noise which exceeded the limit. Patterson and Mozo (1987) showed that the same protection was adequate for the noise of a shoulder-fired antiarmor weapon which also exceeded the protected limit. These results are clearly contradictory to our current exposure limits. One possible explanation is that the 29 dB protection factor is not correct for all hearing protectors. It is known that the foam earplugs provide large amounts of attenuation when they are properly used as they were in these studies. Unfortunately, direct estimates of the amount of protection cannot be derived from these results. While these studies showed that the earplugs used provided adequate protection, they did not establish an upper bound on the noise levels for which they are adequate.

In order to establish upper bounds for exposure to the high intensity impulse noise typical of most heavy weapons, a series of studies was undertaken in the United States. These studies used a common approach with only the exposure impulse changing between studies. Both the level and the number of impulses were varied. Volunteers were given a series of exposures starting with six impulses at a level below current exposure limits. On successive exposure days, the level was raised while the number of impulses remained fixed at six. This process was repeated until a significant threshold shift (over 25 dB at any frequency) was observed or until the threshold of nonauditory injury (Dodd et al., 1990) was reached. Then the number of impulses was increased and exposures continued at a reduced level. The numbers of impulses used were 6, 12, 25, 50, and 100. The goal was to find the lowest level for each number of impulses which resulted in a significant threshold shift (TS). Approximately 60 volunteers, military personnel with less than 5 years of service, participated in each study.

Table 1. Average peak pressures and durations for the impulses at 5 meters from the source.

Intensity code	Peak (kPa)	Peak (dB)	A-duration (ms)	B-duration (ms)	C-duration (ms)	D-duration (ms)
1	10	174	2.3	15.6	1.7	6.0
2	14	177	2.5	17.4	2.0	7.8
3	19	180	2.6	17.2	2.1	7.8
4	26	182	2.9	18.0	2.3	7.6
5	36	185	2.8	18.9	2.6	8.2
6	49	188	2.9	20.0	2.8	9.9
7	69	191	3.0	21.2	2.8	8.3

The first of these (Patterson and Johnson, 1990) used impulses typical of artillery weapons. These impulses were produced by detonation of explosive material 5 meters from the location of the volunteers and approximately 3 meters above the ground. Figure 1a shows a typical

pressure-time signature for this impulse. Table 1 shows the average levels and durations for the series of intensities.

The study design initially included three levels of hearing protection. The plan was to find the limit of the poorest protector first; then to find the limit for improved protection; and finally, to find the limit for the maximum protection. The first hearing protector used was an earmuff compatible with the U.S. Army infantry helmet. The second and third levels were the foam earplugs and the foam earplugs combined with the earmuff; however, these were never used for reasons which will become obvious. Figure 2 shows the attenuation of the earmuff.

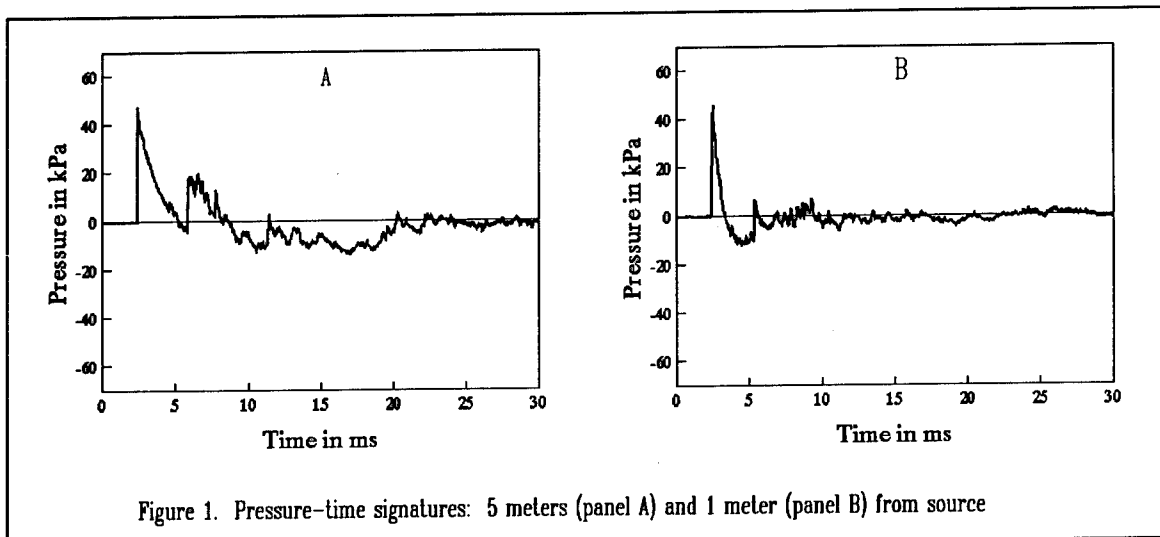


Figure 1. Pressure-time signatures: 5 meters (panel A) and 1 meter (panel B) from source

The first group of volunteers started the study using the earmuff. Forty-nine of these were exposed to 6 impulses at 190 dB SPL and 39 also were exposed up to the 100 impulses at 187 dB SPL. None showed any significant TS. This led to a change in the study design. The hearing protection became the same earmuff modified by introducing intentional leaks in the ear seals. The attenuation at octave frequencies for the modified earmuff also is shown in Figure 2. Notice the low frequency attenuation has been eliminated and the high frequency attenuation reduced. This attenuation is typical of what might be found with a poor fit of the standard earmuff in which the seal is compromised.

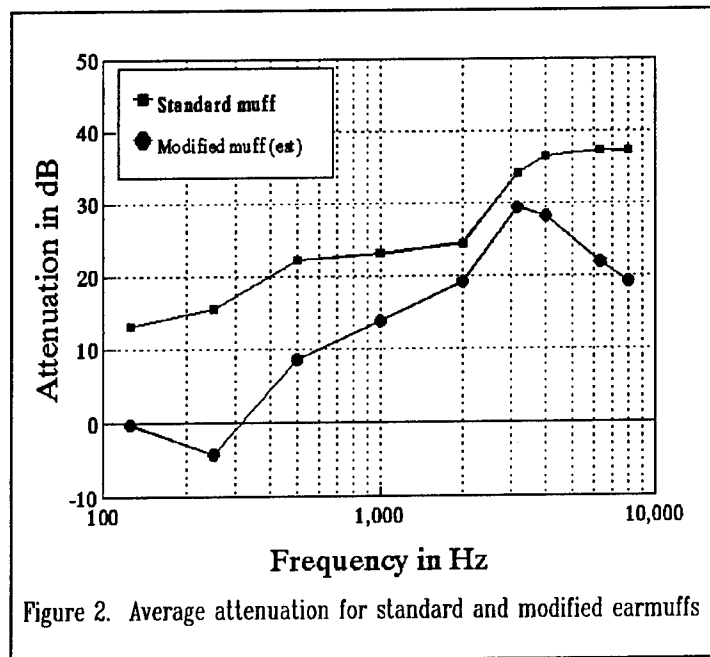


Figure 2. Average attenuation for standard and modified earmuffs

Another group of 60 volunteers was exposed wearing the modified earmuff. This time 56 volunteers progressed to the exposure to 6 impulses at 190 dB SPL with only one showing a significant TS; 58 were exposed up to 100 impulses at 187 dB SPL with only 2 showing a significant TS. These results were interpreted to indicate that the modified earmuffs provide adequate protection for all exposure conditions used in this study.

For the next study (Patterson and Johnson, 1993), the exposure stimuli were produced by detonating explosive material inside a 60 cm diameter steel tube. The volunteers were located so their heads were approximately 1 meter from the open

end of the tube. The pressure-time signature for this impulse is shown in Figure 1b. Table 2 contains the levels and durations for the intensity levels used in this study. The first level hearing protection was the modified earmuffs described earlier. All other procedures remained the same.

Table 2. Average peak pressures and durations for the impulses at 1 meter from the source.

Intensity code	Peak (kPa)	Peak (dB)	A-duration (ms)	B-duration (ms)	C-duration (ms)	D-duration (ms)
1	16	178	1.1	10.8	1.2	2.5
2	23	181	1.0	12.1	1.0	2.2
3	34	185	0.9	9.5	0.7	1.9
4	48	188	0.9	10.8	0.6	1.3
5	66	190	0.8	15.4	0.6	0.8
6	94	193	0.8	53.8	0.5	0.7
7	130	196	0.8	65.0	1.0	1.2

Sixty-five volunteers started the study and 59 progressed to the exposure to 6 impulses at 196 dB SPL. Of these, four showed significant TS at the highest level. Statistically the hypothesis that 95 percent of the exposed population is protected adequately can be rejected when 6 or

more volunteers show a significant TS. Therefore, the modified earmuffs provide adequate protection for 6 impulses at 196 dB. For exposure to 12 impulses at 193 db SPL, 6 of the 61 volunteers showed a significant TS. The protection is considered inadequate for this condition as well as the 193 dB level for more than 12 impulses. At 190 dB SPL, only 4 of 59 volunteers showed a significant TS after exposure to 25 impulses; while at 50 impulses resulted in 7 out of 55 volunteers with a significant TS. At this level, the protection becomes inadequate between 25 and 50 impulses. At 188 dB SPL, the modified earmuff provided adequate protection for all numbers of impulses; 50 impulses produced significant TS in only 3 of 51 volunteers and 100 impulses at this level resulted in significant TS in only 3 of 44 volunteers. These results are summarized in Table 3. The protection provided by the unmodified earmuff was considered adequate for all exposure conditions included in this study.

While these studies were being conducted in the U.S., French researchers were conducting a complementary set of studies (Dancer et al., 1992). The U.S. studies focused on large numbers of volunteers exposed under the same conditions for statistical reliability and included

Table 3. Summary of conditions for which the modified earmuffs provide adequate protection for combinations of level and number of impulses.

Level	Number of impulses				
	6	12	25	50	100
196	A	NA	NA	NA	NA
193	A	U	U	U	U
190	A	A	A	U	U
188	A	A	A	A	A

A=adequate, U=inadequate, NA=exceeds nonauditory limit

only two hearing protector conditions, both earmuffs. In contrast, the French studies used more different hearing protectors, all earplugs, with a smaller number of volunteers for each exposure condition. They also focused on protectors with little or no low frequency attenuation in an effort to maintain face-to-face voice communication. The U.S. studies used explosives to achieve exposure levels exceeding those produced by existing weapons; the French studies used a variety of weapons.

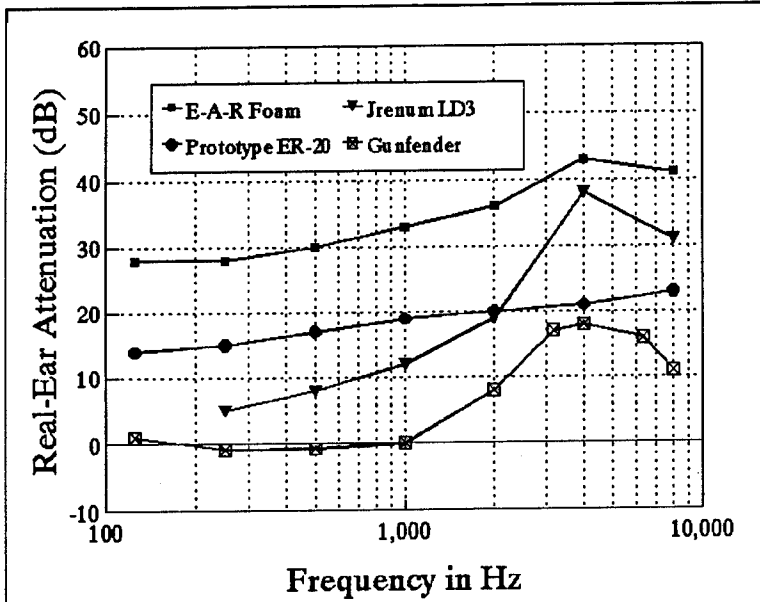


Figure 3. Attenuation of the protectors in the first experiment

Figure 3 shows the attenuation of the hearing protectors used in the first French experiment. Note that the foam plug is the same as that used by Patterson et al. (1985) and Patterson and Mozo (1987). The other protectors are designed to have low attenuation compared to the foam plug. In this experiment, between 6 and 20 volunteers were exposed to the firing of the howitzer for 10 to 20 rounds. The peak levels were between 175 and 176 dB SPL. No TS exceeding 15 dB was observed after these exposures. These results for the foam earplug are not surprising in view of the findings of

Patterson et al. (1985); however, the results for the Gunfender are surprising since it has no attenuation up to 1.0 kHz. This may be a result of its reported growth of attenuation with level (Forrest and Coles, 1969).

In the second experiment, Dancer et al. (1992) used five different hearing protectors. Figure 4 shows the attenuation of these protectors. Three to 5 volunteers were exposed to the rifle fired in a reverberant space (peak levels of 150 to 161 dB SPL), an antitank weapon (peak levels of 182 to 183 dB SPL at the right ear and 178 to 181 dB SPL at the left ear), and to the howitzer (peak levels of 175 to 176 dB SPL). None of the volunteers showed a TS which exceeded the 25 dB criterion used in the U.S. studies to define unacceptable TS. There is no evidence that

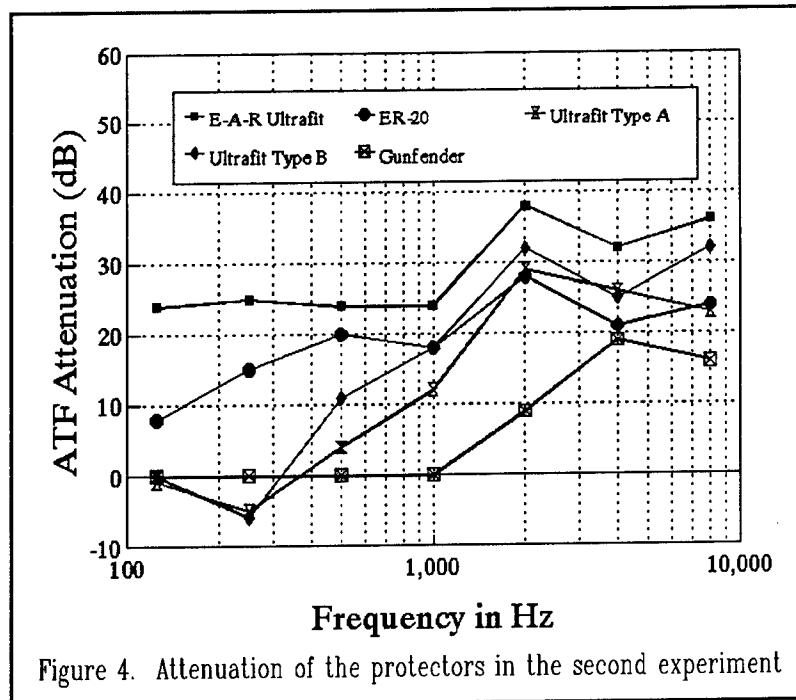


Figure 4. Attenuation of the protectors in the second experiment

any of the protectors used in these experiments fail to provide adequate protection. These studies indicate that a variety of protectors with little attenuation at the low frequencies can provide adequate protection for high intensity weapons noise.

Levels under hearing protection: The third approach to estimating the effectiveness of hearing protectors for high intensity impulse noise is to measure the pressure-time signature under the protector and compare the measured parameters to the unprotected exposure limit. This approach differs from the approach of raising the unprotected limit by a protection value in that it is based on the specific protector and the specific impulse. Recently, Pekkarinian et al. (1992) applied this method to heavy weapons noise and concluded that the levels under the earmuffs exceeded the unprotected limits from both CHABA and Pfander. Johnson and Patterson (1992) also have reported that the levels under the earmuffs of the volunteers participating in the studies described above greatly exceed the unprotected limits. However, in this case the lack of any effect on hearing was documented. This indicates that levels measured under hearing protectors should not be compared to unprotected limits to estimate the effectiveness of the hearing protection.

Summary: There is no generally accepted method for calculating the protection against high intensity impulse noise afforded by hearing protectors. Of the three possible approaches, the use of fixed protection values independent of the hearing protector, have been shown to underestimate the actual effectiveness of hearing protectors. Studies designed to determine the actual effectiveness of hearing protectors are the best, but most costly approach. These studies have shown that protection is adequate for levels which exceed our current exposure limits. Further, these studies clearly demonstrate that the hazard of impulse noise cannot be evaluated by measuring under the hearing protector and using unprotected exposure criteria. This approach generally will lead to a gross underestimate of the actual effectiveness of the hearing protector.

ACKNOWLEDGEMENT

The authors thank Dr. A. Dancer for his French translation of the abstract for this paper.

References:

- CHABA (1968). Proposed damage-risk criterion for impulse noise (gunfire), Committee on Hearing, Bioacoustics and Biomechanics, National Academy of Sciences, National Research Council, edited by W.D. Ward, Report of Working Group 57.
- Coles, R.R.A., Garinther, G.R., Hodge, D.C., and Rice, C.G. (1968). Hazardous exposure to impulse noise. *J. Acoust. Soc. Am.* 43:336-346.
- Dancer, A, Grateau, P., Cabanis, A., Barnabe, Gilles, Cagnin, Gilles, Vaillant, T., and Lafont, D. (1992). Effectiveness of earplugs in high-intensity impulse noise. *J. Acoust. Soc. Am.* 91(3).
- Department of Defense, USA. (1979). Military standard: Noise limits for Army material, MIL-STD-1474B (M1). Washington, DC.
- Dodd, K.T., Yelverton, J.T., Richmond, D.R., Morris, J.R., and Ripple, G.R. (1990). Nonauditory injury threshold for repeated intense freefield impulse noise. *J. of Occup. Med.* 32(3) 260-266.

- Forrest, M.R. and Coles, R.R.A. (1969). Use of cadaver ears in the acoustic evaluation of ear plugs, Medical Research Council, Royal Naval Personnel Research Committee, Great Britain, HeS 134, 1-37.
- Garinther, G.R., and Hodge, D.C. (1971). Small-rocket noise: Hazards to hearing (advanced LAW program) (Technical Memorandum 7-71). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory.
- Garinther, G.R., and Hodge, D.C. (1981). The background and bases for the proposed military standard on acoustical noise limits in helicopters (Technical Memorandum 5-81). Aberdeen Proving Ground, MD: U.S. Human Engineering Laboratory.
- Johnson, D.L., and Patterson, J.H., Jr. (1992). Rating of hearing protector performance for impulse noise. Proceedings 1992 Hearing Conservation Conference, Lexington, KY: Office of Engineering Services, College of Engineering, University of Kentucky.
- Patterson, J.H., Jr., and Johnson, D.L. (1990). Determination of occupational noise exposure limits for very high intensity impulses when hearing protection is used. J. Acoust. Soc. Am. 88(1).
- Patterson, J.H., Jr. and Johnson, D.L. (1993). Effects of high-intensity impulse noise on the hearing of humans wearing hearing protection. J. Acoust. Soc. Am. 93(4).
- Patterson, J.H., Jr., and Mozo, B.T. (1987). Direct determination of the adequacy of hearing protection for use with the VIPER. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory, USAARL Report No. 87-9.
- Patterson, J.H., Mozo, B.T., Marrow, R.H., McConnell, R.W., Lomba Gautier, I.M., Curd, D.L., Phillips, Y.Y., and Henderson, R. (1985). Direct determination of the adequacy of hearing protection devices for use with the M198 155 mm towed howitzer. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory, USAARL Report No. 85-14.
- Pekkarinen, J.O., Starck, J.P. and Ylikoski, J.S. (1992). Hearing protection against high-level shooting impulses in relation to hearing damage risk criteria. J. Acoust. Soc. Am. 91(1).
- Pfander, F. (1975). Das Knalltrauma, Berlin: Springer-Verlag.

Initial distribution

Commander, U.S. Army Natick Research,
Development and Engineering Center
ATTN: SATNC-MIL (Documents
Librarian)
Natick, MA 01760-5040

Library
Naval Submarine Medical Research Lab
Box 900, Naval Sub Base
Groton, CT 06349-5900

Chairman
National Transportation Safety Board
800 Independence Avenue, S.W.
Washington, DC 20594

Executive Director, U.S. Army Human
Research and Engineering Directorate
ATTN: Technical Library
Aberdeen Proving Ground, MD 21005

Commander
10th Medical Laboratory
ATTN: Audiologist
APO New York 09180

Commander
Man-Machine Integration System
Code 602
Naval Air Development Center
Warminster, PA 18974

Naval Air Development Center
Technical Information Division
Technical Support Detachment
Warminster, PA 18974

Commander
Naval Air Development Center
ATTN: Code 602-B
Warminster, PA 18974

Commanding Officer, Naval Medical
Research and Development Command
National Naval Medical Center
Bethesda, MD 20814-5044

Commanding Officer
Armstrong Laboratory
Wright-Patterson
Air Force Base, OH 45433-6573

Deputy Director, Defense Research
and Engineering
ATTN: Military Assistant
for Medical and Life Sciences
Washington, DC 20301-3080

Director
Army Audiology and Speech Center
Walter Reed Army Medical Center
Washington, DC 20307-5001

Commander, U.S. Army Research
Institute of Environmental Medicine
Natick, MA 01760

Commander/Director
U.S. Army Combat Surveillance
and Target Acquisition Lab
ATTN: SFAE-IEW-JS
Fort Monmouth, NJ 07703-5305

Director
Federal Aviation Administration
FAA Technical Center
Atlantic City, NJ 08405

Commander, U.S. Army Test
and Evaluation Command
Directorate for Test and Evaluation
ATTN: AMSTE-TA-M (Human Factors
Group)
Aberdeen Proving Ground,
MD 21005-5055

Naval Air Systems Command
Technical Air Library 950D
Room 278, Jefferson Plaza II
Department of the Navy
Washington, DC 20361

Director
U.S. Army Ballistic
Research Laboratory
ATTN: DRXBR-OD-ST Tech Reports
Aberdeen Proving Ground, MD 21005

Commander
U.S. Army Medical Research
Institute of Chemical Defense
ATTN: SGRD-UV-AO
Aberdeen Proving Ground,
MD 21010-5425

Commander
USAMRDALC
ATTN: SGRD-RMS
Fort Detrick, Frederick, MD 21702-5012

Director
Walter Reed Army Institute of Research
Washington, DC 20307-5100

HQ DA (DASG-PSP-O)
5109 Leesburg Pike
Falls Church, VA 22041-3258

Harry Diamond Laboratories
ATTN: Technical Information Branch
2800 Powder Mill Road
Adelphi, MD 20783-1197

U.S. Army Materiel Systems
Analysis Agency
ATTN: AMXSU-PA (Reports Processing)
Aberdeen Proving Ground
MD 21005-5071

U.S. Army Ordnance Center
and School Library
Simpson Hall, Building 3071
Aberdeen Proving Ground, MD 21005

U.S. Army Environmental
Hygiene Agency
ATTN: HSHB-MO-A
Aberdeen Proving Ground, MD 21010

Technical Library Chemical Research
and Development Center
Aberdeen Proving Ground, MD
21010-5423

Commander
U.S. Army Medical Research
Institute of Infectious Disease
ATTN: SGRD-UIZ-C
Fort Detrick, Frederick, MD 21702

Director, Biological
Sciences Division
Office of Naval Research
600 North Quincy Street
Arlington, VA 22217

Commandant
U.S. Army Aviation
Logistics School ATTN: ATSQ-TDN
Fort Eustis, VA 23604

Headquarters (ATMD)
U.S. Army Training
and Doctrine Command
ATTN: ATBO-M
Fort Monroe, VA 23651

IAF Liaison Officer for Safety
USAF Safety Agency/SEFF
9750 Avenue G, SE
Kirtland Air Force Base
NM 87117-5671

Naval Aerospace Medical
Institute Library
Building 1953, Code 03L
Pensacola, FL 32508-5600

Command Surgeon
HQ USCENTCOM (CCSG)
U.S. Central Command
MacDill Air Force Base, FL 33608

Director
Directorate of Combat Developments
ATTN: ATZQ-CD
Building 515
Fort Rucker, AL 36362

U.S. Air Force Institute
of Technology (AFIT/LDEE)
Building 640, Area B
Wright-Patterson
Air Force Base, OH 45433

Henry L. Taylor
Director, Institute of Aviation
University of Illinois-Willard Airport
Savoy, IL 61874

Chief, National Guard Bureau
ATTN: NGB-ARS
Arlington Hall Station
111 South George Mason Drive
Arlington, VA 22204-1382

Commander
U.S. Army Aviation and Troop Command
ATTN: AMSAT-R-ES
4300 Goodfellow Bouvelard
St. Louis, MO 63120-1798

U.S. Army Aviation and Troop Command
Library and Information Center Branch
ATTN: AMSAV-DIL
4300 Goodfellow Boulevard
St. Louis, MO 63120

Federal Aviation Administration
Civil Aeromedical Institute
Library AAM-400A
P.O. Box 25082
Oklahoma City, OK 73125

Commander
U.S. Army Medical Department
and School
ATTN: Library
Fort Sam Houston, TX 78234

Commander
U.S. Army Institute of Surgical Research
ATTN: SGRD-USM
Fort Sam Houston, TX 78234-6200

AAMRL/HEX
Wright-Patterson
Air Force Base, OH 45433

Air University Library
(AUL/LSE)
Maxwell Air Force Base, AL 36112

Product Manager
Aviation Life Support Equipment
ATTN: SFAE-AV-LSE
4300 Goodfellow Boulevard
St. Louis, MO 63120-1798

Commander and Director
USAE Waterways Experiment Station
ATTN: CEWES-IM-MI-R,
CD Department
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Commanding Officer
Naval Biodynamics Laboratory
P.O. Box 24907
New Orleans, LA 70189-0407

Assistant Commandant
U.S. Army Field Artillery School
ATTN: Morris Swott Technical Library
Fort Sill, OK 73503-0312

Mr. Peter Seib
Human Engineering Crew Station
Box 266
Westland Helicopters Limited
Yeovil, Somerset BA20 2YB UK

U.S. Army Dugway Proving Ground
Technical Library, Building 5330
Dugway, UT 84022

U.S. Army Yuma Proving Ground
Technical Library
Yuma, AZ 85364

AFFTC Technical Library
6510 TW/TSTL
Edwards Air Force Base,
CA 93523-5000

Commander
Code 3431
Naval Weapons Center
China Lake, CA 93555

Aeromechanics Laboratory
U.S. Army Research and Technical Labs
Ames Research Center, M/S 215-1
Moffett Field, CA 94035

Sixth U.S. Army
ATTN: SMA
Presidio of San Francisco, CA 94129

Commander
U.S. Army Aeromedical Center
Fort Rucker, AL 36362

Strughold Aeromedical Library
Document Service Section
2511 Kennedy Circle
Brooks Air Force Base, TX 78235-5122

Dr. Diane Damos
Department of Human Factors
ISSM, USC
Los Angeles, CA 90089-0021

U.S. Army White Sands
Missile Range
ATTN: STEWS-IM-ST
White Sands Missile Range, NM 88002

U.S. Army Aviation Engineering
Flight Activity
ATTN: SAVTE-M (Tech Lib) Stop 217
Edwards Air Force Base, CA 93523-5000

Ms. Sandra G. Hart
Ames Research Center
MS 262-3
Moffett Field, CA 94035

Commander
USAMRDALC
ATTN: SGRD-UMZ
Fort Detrick, Frederick, MD 21702-5009

Commander
U.S. Army Health Services Command
ATTN: HSOP-SO
Fort Sam Houston, TX 78234-6000

U. S. Army Research Institute
Aviation R&D Activity
ATTN: PERI-IR
Fort Rucker, AL 36362

Commander
U.S. Army Safety Center
Fort Rucker, AL 36362

U.S. Army Aircraft Development
Test Activity
ATTN: STEBG-MP-P
Cairns Army Air Field
Fort Rucker, AL 36362

Commander
USAMRDALC
ATTN: SGRD-PLC (COL R. Gifford)
Fort Detrick, Frederick, MD 21702

TRADOC Aviation LO
Unit 21551, Box A-209-A
APO AE 09777

Netherlands Army Liaison Office
Building 602
Fort Rucker, AL 36362

British Army Liaison Office
Building 602
Fort Rucker, AL 36362

Italian Army Liaison Office
Building 602
Fort Rucker, AL 36362

Directorate of Training Development
Building 502
Fort Rucker, AL 36362

Chief
USAHEL/USAAVNC Field Office
P. O. Box 716
Fort Rucker, AL 36362-5349

Commander, U.S. Army Aviation Center
and Fort Rucker
ATTN: ATZQ-CG
Fort Rucker, AL 36362

Chief
Test & Evaluation Coordinating Board
Cairns Army Air Field
Fort Rucker, AL 36362

Canadian Army Liaison Office
Building 602
Fort Rucker, AL 36362

German Army Liaison Office
Building 602
Fort Rucker, AL 36362

French Army Liaison Office
USAAVNC (Building 602)
Fort Rucker, AL 36362-5021

Australian Army Liaison Office
Building 602
Fort Rucker, AL 36362

Dr. Garrison Rapmund
6 Burning Tree Court
Bethesda, MD 20817

Commandant, Royal Air Force
Institute of Aviation Medicine
Farnborough, Hampshire GU14 6SZ UK

Defense Technical Information
Cameron Station, Building 5
Alexandra, VA 22304-6145

Commander, U.S. Army Foreign Science
and Technology Center
AIFRTA (Davis)
220 7th Street, NE
Charlottesville, VA 22901-5396

Commander
Applied Technology Laboratory
USARTL-ATCOM
ATTN: Library, Building 401
Fort Eustis, VA 23604

Commander, U.S. Air Force
Development Test Center
101 West D Avenue, Suite 117
Eglin Air Force Base, FL 32542-5495

Aviation Medicine Clinic
TMC #22, SAAF
Fort Bragg, NC 28305

Dr. H. Dix Christensen
Bio-Medical Science Building, Room 753
Post Office Box 26901
Oklahoma City, OK 73190

Commander, U.S. Army Missile
Command
Redstone Scientific Information Center
ATTN: AMSMI-RD-CS-R
/ILL Documents
Redstone Arsenal, AL 35898

Director
Army Personnel Research Establishment
Farnborough, Hants GU14 6SZ UK

U.S. Army Research and Technology
Laboratories (AVSCOM)
Propulsion Laboratory MS 302-2
NASA Lewis Research Center
Cleveland, OH 44135

Commander
USAMRDALC
ATTN: SGRD-ZC (COL John F. Glenn)
Fort Detrick, Frederick, MD 21702-5012

Dr. Eugene S. Channing
166 Baughman's Lane
Frederick, MD 21702-4083

U.S. Army Medical Department
and School
USAMRDALC Liaison
ATTN: HSMC-FR
Fort Sam Houston, TX 78234

Dr. A. Kornfield
895 Head Street
San Francisco, CA 94132-2813

NVESD
AMSEL-RD-NV-ASID-PST
(Attn: Trang Bui)
10221 Burbeck Road
Fort Belvoir, VA 22060-5806

CA Av Med
HQ DAAC
Middle Wallop
Stockbridge, Hants S020 8DY UK

Dr. Christine Schlichting
Behavioral Sciences Department
Box 900, NAVUBASE NLON
Groton, CT 06349-5900

Aerospace Medicine Team
HQ ACC/SGST3
162 Dodd Boulevard, Suite 100
Langley Air Force Base,
VA 23665-1995

Commander
Aviation Applied Technology Directorate
ATTN: AMSAT-R-TV
Fort Eustis, VA 23604-5577

COL Yehezkel G. Caine, MD
Surgeon General, Israel Air Force
Aeromedical Center Library
P. O. Box 02166 I.D.F.
Israel

HQ ACC/DOHP
205 Dodd Boulevard, Suite 101
Langley Air Force Base,
VA 23665-2789

41st Rescue Squadron
41st RQS/SG
940 Range Road
Patrick Air Force Base,
FL 32925-5001

48th Rescue Squadron
48th RQS/SG
801 Dezonias Road
Holloman Air Force Base,
NM 88330-7715

35th Fighter Wing
35th FW/SG
PSC 1013
APO AE 09725-2055

66th Rescue Squadron
66th RQS/SG
4345 Tyndall Avenue
Nellis Air Force Base, NV 89191-6076

71st Rescue Squadron
71st RQS/SG
1139 Redstone Road
Patrick Air Force Base,
FL 32925-5000

Director
Aviation Research, Development
and Engineering Center
ATTN: AMSAT-R-Z
4300 Goodfellow Boulevard
St. Louis, MO 63120-1798

Commander
USAMRDALC
ATTN: SGRD-ZB (COL C. Fred Tyner)
Fort Detrick, Frederick, MD 21702-5012

Commandant
U.S. Army Command and General Staff
College
ATTN: ATZL-SWS-L
Fort Leavenworth, KS 66027-6900