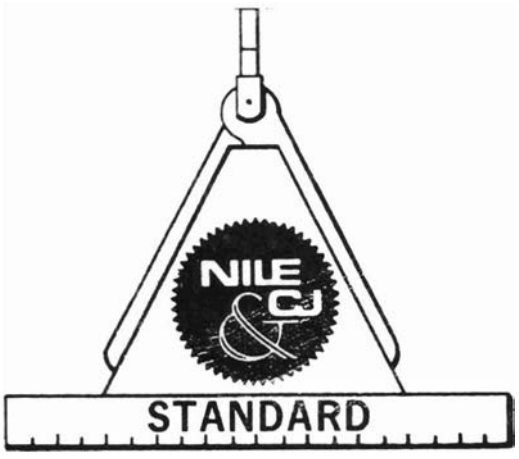
NILECJ-STD-0102.00
MARCH 1973

LAW ENFORCEMENT STANDARDS PROGRAM

HEARING PROTECTORS FOR USE ON FIRING RANGES



U.S. DEPARTMENT OF JUSTICE
Law Enforcement Assistance Administration
National Institute of Law Enforcement and Criminal Justice

LAW ENFORCEMENT STANDARDS PROGRAM

NILECJ STANDARD

HEARING PROTECTORS FOR USE ON FIRING RANGES

A Voluntary National Standard Promulgated by the National Institute of Law Enforcement and Criminal Justice.

MARCH, 1973

U.S. DEPARTMENT OF JUSTICE

Law Enforcement Assistance Administration
National Institute of Law Enforcement and Criminal Justice

For sole by the Superintendent of Documents, U.S. Government Printing Office
Washington. D.C. 20402. Price: 40 cents. domestic postpaid; 30 cents, GPO Bookstore
Stock No. 2700–00182

LAW ENFORCEMENT ASSISTANCE ADMINISTRATION

Jerris Leonard
Administrator

Richard W. Velde
Clarence M. Coster
Associate Administrators

NATIONAL INSTITUTE OF LAW ENFORCEMENT AND CRIMINAL JUSTICE
Martin B. Danziger, *Assistant Administrator*

RESEARCH ADMINISTRATION **DIVISION**
Harry Bratt, *Director*

EQUIPMENT SYSTEMS **IMPROVEMENT** PROGRAM
Joseph T. Kochanski, *Manager*

STANDARDS PROGRAM
Lester D. Shubin, *Manager*

ACKNOWLEDGEMENTS

This standard was formulated by the Law Enforcement Standards Laboratory of the National Bureau of Standards under the direction of Jacob J. Diamond, Manager, Protective Equipment Program, and Chief of LESL. The technical work was performed by Pearl G. Weissler of the NBS Mechanics Division. Linda K. Smith did the typing and assisted with the editing and final copy preparation.

NILECJ Standard
for
Hearing Protectors for Use on Firing Ranges

CONTENTS

FOREWORD

In accordance with Title I, Section 402(b) of the Omnibus Crime Control and Safe Streets Act of 1968, P.L. 90-351, the National Institute of Law Enforcement and Criminal Justice (NILECJ) has established the Law Enforcement Standards Laboratory (LESL) at the National Bureau of Standards.

LESL has been established to conduct research leading to the development and promulgation of national voluntary equipment standards that will assist law enforcement and criminal justice agencies in the selection and procurement of quality equipment. In the course of standards development, LESL is defining minimum performance levels and developing methods for measuring the required performance of equipment designated by NILECJ.

This document, NILECJ ***Standard for Hearing Protectors for Use on Firing Ranges,*** is a law enforcement equipment standard developed by LESL and issued by NILECJ. Additional standards, as well as user guidelines, state-of-the-art surveys, and other reports are planned for issuance under the LESL program in the areas of protective equipment, communications equipment, security systems, weapons, emergency equip ment, concealed objects detectors, and vehicles.

NILECJ Standards are subjected to continuing review. Technical comments and recommended revisions are invited from all interested parties. Suggestions should be addressed to the Program Manager for Standards, National Institute of Law Enforcement and Criminal Justice, Law Enforcement Assistance Administration, U.S. Department of Justice, Washington, D.C. 20530.

NILECJ STANDARD
for
HEARING PROTECTORS FOR USE ON FIRING RANGES

1. PURPOSE AND SCOPE

The purpose of this standard is to establish performance requirements and methods of test for wearable devices used to protect the auditory system against the excessive sound encountered on firing ranges.

The described test method measures hearing protection by means of psychoacoustic tests on human subjects, and is based on a method long in use to evaluate protectors worn in continuous steady noise situations. No practical procedure is yet available to directly determine protection against the impulsive noise encountered on firing ranges; a brief discussion of the state-of-the-art is given in appendix A.

Nonlinear or amplitude-sensitive devices are not evaluated by the psychoacoustic procedure contained in this standard, and consequently the effectiveness of their special features cannot be determined.

2. CLASSIFICATION

The following types of hearing protectors are covered in this standard.

2.1 Earplugs

2.2 Earmuffs

2.3 Earplugs and Earmuffs Worn in Combination

3. DEFINITIONS

3.1 Ear Implantation

The join between the ear and the head.

3.2 Hearing Level (of an ear)

The amount in decibels by which the threshold of audibility for an ear exceeds a standard normal threshold.

3.3 Hearing Protector

A device that is worn to reduce the effect of sound on the auditory system

3.4 Impulsive Noise

A noise characterized by brief excursions of sound pressure (acoustic impulses) which significantly exceed the ambient noise. The duration of a single impulse is usually less than 1 second.

3.5 Nonlinear or Amplitude-Sensitive Hearing Protector

A hearing protector whose attenuation is a function of the sound pressure level.

3.6 Occluded Threshold of Audibility

The minimum sound pressure level of a specified signal that is capable of evoking an auditory sensation in a specific fraction of trials when a hearing protector is worn.

3.7 Open Threshold of Audibility

The minimum sound pressure level of a specified signal that is capable of evoking an auditory sensation in a specified fraction of trials when a hearing protector is not worn,

3.8 Real-Ear Protection at Threshold

The mean value of the occluded threshold of audibility in decibels minus the open threshold of audibility in decibels for all listeners on all trials.

3.9 Sound Pressure Level (in decibels [dB])

Twenty times the logarithm to the base 10 of the ratio of the pressure of a sound to the reference sound pressure. Unless otherwise specified, the effective (root-mean-square) pressure is to be understood. The reference sound pressure is 20 micropascals (20 μPa).

3.10 Steady Noise

A noise whose sound pressure level remains essentially constant (that is, fluctuations are negligibly small) during the period of observation.

4. REQUIREMENTS

4.1 Sampling for Test

A sample of at least 10 sets of hearing protectors, consistent with the requirements of sections 5.4.1 and 5.6, shall be selected for test at random, using a set of random numbers or an equivalent procedure.

4.2 Real-Ear Protection at Threshold

The hearing protector, when used in accordance with the manufacturer's instructions and tested in accordance with section 5, shall provide minimum real-ear protection at threshold as set forth in table 1.

TABLE 1. – *Real-Ear Protection at Threshold Requirements**

Group	Test frequencies (Hz)	Minimum group protection** (decibels)		Minimum single frequency protection (decibels)	
		Muffs	Plugs	Muffs	Plugs
A.....	125	25	25	None	None
	250			None	None
B.....	500	185	135	25	20
	1000			35	None
	2000			35	None
	3000			35	None
	4000			35	None
C.....	6000	60	55	None	None
	8000			None	None

*This standard does not apply to nonlinear or amplitude-sensitive devices.
**The group protection is the sum of the real-ear protections at threshold for all of the test frequencies in that group.

4.3 Materials

4.3.1 Hearing protectors intended to be used more than once shall be made of materials that are capable of being easily cleaned and disinfected.

4.3.2 Materials coming into contact with the body shall not be harmful or irritating, and shall be resistant to damage by skin oil, hair oil, and ear wax.

4.3.3 Where applicable, protectors shall comply with anthropometric data for head and ear sizes falling within the 5th and 95th percentile range, as given in figure 1. This is not intended to exclude earmuffs whose dimensions are based upon ear implantation measurements.

4.4 User Information

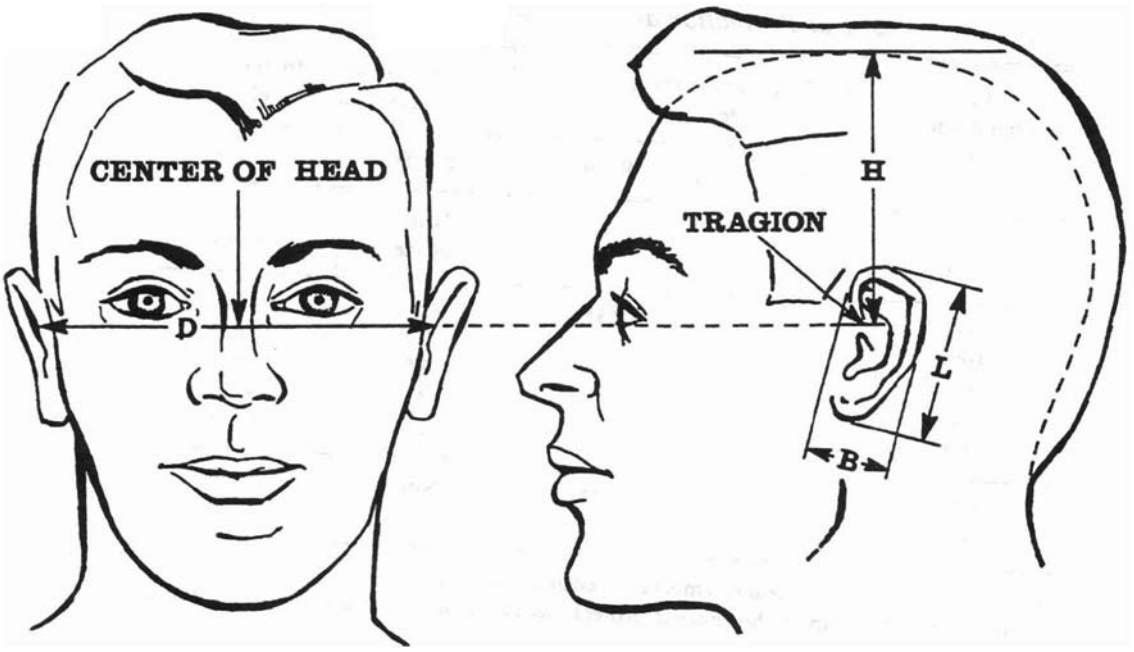
4.4.1 User Manual

The following items of information regarding the construction, performance and use of hearing protectors shall be provided by the manufacturer to the user:

(a) Real-ear protection at threshold at the nine test frequencies given in table I, including identification of the testing organization.
(b) Overall weight.
(c) Any conditions such as temperature under which the protector should not be used.
(d) Instructions for cleaning, disinfecting, maintenance, and use.
(e) List of available spare parts.

4.4.2 Marking

Hearing protectors shall be permanently marked with the model number and manufacturer's name. Earplugs shall be marked on the container and earmuffs shall be marked on the muffs themselves.



Dimension	5th percentile		95th percentile	
	mm	in	mm	in
Head height = H	117	4.61	142	5.59
Head width = D	128	5.04	156	6.14
Ear length = L	56	2.21	72	2.84
Ear breadth = B	30	1.19	41	1.61

FIGURE 1.—*Anthropometric Dimensions*

5. TEST METHODS

5.1 Test Room

5.1.1 Ambient Noise

The ambient noise at the position of the listener (see 5.4) in the test room shall not exceed the values given in table 2 with the listener absent from the room, with instrumentation on and no test signal present.

In addition, there should be no noise audible to the listener when the listener is seated in the test room, with instrumentation on and no test signal present

5.1.2 Room Interior Characteristics

The objective should be a sound field such that, with reasonable unavoidable movement of the head, the sound level at the listener's ears does not change significantly. An anechoic or anechoic-like chamber is required to obtain this sound field. A room interior and the positions of the listener and loudspeaker will satisfy requirements if, at all test frequencies up to and including 4000 Hz, the sound pressure level remains within a range of 6 dB as a microphone is moved, relative to the position of the center of the listener's

head (see fig. 1), ± 3 inches in the front-back, ± 6 inches in the up-down and ± 6 inches in the left-right dimensions. The difference between sound pressure levels at the extreme left-right positions shall not exceed 2 dB. These measurements are to be made when the listener is absent from the room.

TABLE 2.— ***Maximum Permissible Ambient Noise in Octave Bands***

Frequency in hertz			Level in decibels (reference 20 μPa)
Limits		Center	
90	180	125	24.5
180	355	250	18.5
355	710	500	16.0
710	1400	1000	16.0
1400	2800	2000	14.0
2800	5600	4000	9.5
5600	11000	8000	21.0

5.2 Test Signals

Pure tones shall be used as test signals for measuring real-ear protection at threshold for at least the following frequencies: 125,250,500, 1000,2000,3000,4000,6000 and 8000 Hz. Interrupted tones, or pulsed tones with a 50 percent duty cycle, without audible transients and with an "on time" of 1 second shall be used.

5.3 Apparatus

5.3.1 Signal Generator

A pure-tone oscillator shall be used which is capable of supplying sinusoidal voltage at each of the test frequencies specified in 5.2. The frequency provided shall be accurate within ± 1 percent.

5.3.2 On-Off Switch

The signal on-off switch shall operate in such a manner that no transients or extraneous frequencies are audible to the listener. After operation of the switch, the time required for the sound pressure of the test signal to rise from –20 dB to –1 dB relative to its final steady value shall be not less than 0.02 second and not more than 0.1 0 second, and the time required for the sound pressure of the signal to decay by 20 dB shall be not less than 0.005 second and not more than 0.10 second. The operation of the switch shall not cause the output voltage level operating the loudspeaker to attain a value more than one dB above its steady state.

5.3.3 Power Amplifier

The power amplifier shall be capable of furnishing sufficient electrical power to the loudspeaker to produce the signal levels required in 5.3.5. (See 5.1.1 for noise level requirements.)

5.3.4 Attenuator

The attenuator shall include steps of 2 dB or smaller. The choice of attenuator will de-

pend upon the audiometric procedure used (see 5.7.2). If the listener controls the attenuator, a Bekesy-type continuous recording attenuator or a step attenuator may be used In the latter case, an additional attenuator should be controlled by the experimenter. The attenuator shall be calibrated within 1.0 dB or less, and the tolerance between adjacent 2 dB steps shall be no greater than 0.5 dB.

5.3.5 Loudspeaker

The loudspeaker shall be capable of producing a sound pressure level at the listener's position that ranges from 10 dB below the open threshold of audibility at all test frequencies to 10 dB above the occluded threshold of audibility at 125 Hz and 20 dB above the occluded threshold of audibility at the remaining test frequencies.

5.3.6 Distortion

Each component of the apparatus shall be selected so that the entire system produces less than 5 percent total harmonic distortion, measured at the listener's position. No extraneous noise shall be audible under the conditions of use.

5.3.7 Signaling Device

If the experimenter controls the attenuation throughout the test, the listener will require a means of signaling when he hears. Any simple device such as a pushbutton switch that controls a light may be used. If the listener adjusts his own attenuator, the signal could be used to indicate that he has completed a threshold

5.3.8 Head-Positioning Device

Some means shall be provided for maintaining the listener's head in a constant position, facing the center of the loudspeaker. The device shall not transmit to the listener's head any vibrations that might affect the measurements.

5.4 Listeners

5.4.1 Not less than 10 qualified subjects as defined below shall be used

5.4.2 Listeners to be used in the tests described below shall have no more than 10 dB hearing level at any test frequency in either ear as measured by a standard audiometer (ANSI S3.6-1969).

5.4.3 No listener shall be selected as a subject for these tests whose variability for the open threshold of audibility described under 5.7 is such that the range on three successive open threshold measurements at any single test frequency from 500 through 4000 Hz is greater than 6 dB.

5.4.4 Listeners who obtain an adequate acoustic fit with the test item (5.6) may not be dismissed for reporting small amounts of protection if they satisfy the other requirements of this standard.

5.4.5 Listeners shall be completely informed regarding the test situation, procedure and their expected performance (5.4.3).

5.5 Positioning for Test

The listener shall be seated facing the loudspeaker, with his head fixed by the head-

positioning device. The loudspeaker shall be mounted in such a way that its axis is essentially horizontal and directed toward the center of the listener's head. In many rooms it will be found advantageous to place the loudspeaker in one corner so that its axis is along one of the diagonals of the room.

5.6 Installation of Hearing Protectors

Each listener is to be provided with his own personal set of hearing protectors to be used throughout the test. Earplugs shall be inserted or earmuffs shall be put on by the listener himself, while he is seated in the test chair and while in the presence of a white noise over the audible frequency range whose overall sound pressure level at the listener's position is approximately 70 dB above 20 μPa. It shall be the responsibility of the experimenter in charge of the tests to see that the proper size of hearing protector is selected for each listener and to instruct each listener so that the hearing protector is installed according to instructions from the manufacturer. The listener shall also be instructed to manipulate the hearing protectors until the noise appears to be minimal Then the noise shall be turned off.

5.7 Measurement of Threshold of Audibility

5.7.1 The experimenter and all electronic equipment shall be located outside the test room except for the loudspeakers, listener attenuator (if used), and signaling device.

5.7.2 The listener shall be seated in the test room with no signals present for a period of 5 minutes prior to testing to allow him to accommodate to the test situation. At each of the test frequencies (5.2) the attenuation shall be varied until a level is reached at which the signal is just audible. This level is the threshold of audibility. Any standard psychophysical or audiometric technique suitable for threshold determination of pure tones may be used provided the same technique is used throughout the tests.

5.7.3 For each listener, the open threshold for all test frequencies and the occluded threshold for all test frequencies shall be measured consecutively with a short rest period in between. At least three sets of open and occluded thresholds for each listener shall be measured, with a rest period in between sets. The order in which the thresholds are taken in each set (open first or occluded first) shall be alternated.

5.7.4 When a listener non-recording attenuator is used, the experimenter attenuator shall be varied for each presentation so that the level of the test signal presented to the listener attenuator shall differ from trial to trial.

5.8 Test Results

5.8.1 Calculation of Real-Ear Protection at Threshold

The input voltage to the experimenter attenuator and the sum of the experimenter and listener attenuation should be recorded for each trial. For each frequency, the real-ear protection at threshold is equal to the mean voltage level on the loudspeaker corresponding to the occluded threshold of audibility minus the mean voltage level corresponding to the open threshold of audibility for all listeners for all trials, the voltage difference to be expressed in decibels. If the voltage to the experimenter attenuator remained fixed

throughout the test, then the real-ear protection at threshold is simply the mean attenuator setting for the open threshold of audibility minus the mean attenuator setting for the occluded threshold of audibility.

5.8.2 Presentation of Results

The real-ear protection at threshold shall be reported for at least each of the nine specified test frequencies. The data shall be summarized in a table that displays real-ear protection at threshold as a function of frequency.

APPENDIX A

State-of-the-Art for Evaluating Hearing Protectors for Impulsive Sound

It is well known that exposure to excessive sound can cause hearing damage. Ideally, order to prevent damage by means of hearing protectors one must

(a) know the risk of hearing impairment due to exposure to different sounds,
(b) be able to measure the relevant parameters of the sound, and,
(c) through tests on hearing protectors, choose one which will attenuate the sound to safe levels.

These three conditions can be met reasonably well for continuous steady noise. One can measure the noise level with a sound level meter with sufficient accuracy. From established damage risk criteria (see Baughn 1971) one can determine whether the levels present a risk for hearing damage, and (providing the levels are not too high) one can choose a hearing protector from real-ear protection data at threshold and be reasonably certain that for most people the noise will be attenuated to safe levels.

For impulsive noise, such as from gunfire, the situation is not as clear. A tentative damage risk criterion for impulsive noise was recently proposed by the Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) of the National Academy of Sciences-National Research council. The criterion is intended to protect all but the most susceptible 5 percent of exposed individuals. It represents tolerance limits for 100 impulses distributed over a period of 4 minutes to several hours on any single day. The maximum peak pressure level permitted is 164 dB (without ear protection) for the shortest pulses (25 microseconds duration each). As the duration increases, (i.e., from echoes in a reverberant indoor firing range) the permitted peak pressure level decreases, dropping to a terminal level of 138 dB for durations of 200 to 1,000 milliseconds. The permitted level is reduced by 5 dB for each tenfold increase in the number of impulses.

Measurement of the relevant parameters in impulsive noise requires more sophisticated techniques and instrumentation than for steady noise. For the latter, a reading of the output meter of a sound level meter has been found very useful. For impulsive noise such as gunfire, the sound level meter is too slow and cannot follow the sharp rise in sound pressure. Instead, one must use a broad-band transducer such as a small condenser microphone, and a cathode-ray oscilloscope.

Little has been published on the peak pressure levels or the signal durations of the firearms used by policemen. However, Acton and Forrest (1968) found the peak pressure level 2 feet from a short-barrel caliber .22 pistol to be 160 dB. The duration, in an indoor range, was 5 milliseconds. The maximum permitted level for this duration under the CHABA criterion is 148 dB. Therefore the use of hearing protectors is clearly necessary.

No practical procedure has been established for determining how much a hearing protector attenuates the peak pressure level of an impulsive sound. By the extreme method of exposing people to impulsive sounds both with and without hearing protectors, and measuring their temporary threshold shift 2 minutes after exposure (TTS_2), significant data on hearing protectors can be obtained. In this fashion Jacobson, Dyer and Marone (1962) found that properly fitted V51R earplugs attenuated peak pressure levels by more than 20 dB.

Although much data on the real-ear protection at threshold for pure tones are available, a clear relationship with the ability of a hearing protector to attenuate impulse peak pressure levels has not been established. That some relationship does exist seems indicated by the work of Coles and Rice (1966). The real-ear protection at threshold for the V51R earplug and another similar earplug modified to act as a low-pass filter was mea-

sured, and the low-pass feature of the second earplug substantiated. Both earplugs gave adequate protection when worn by men exposed to noise under open range firing conditions. Men exposed to noise under reverberant firing conditions, however, experienced little or no temporary threshold shift when wearing the **VSIR** earplugs, but showed significant TTS_2 in both the low and high frequencies when wearing the second earplug. The authors concluded that both low frequency and high frequency attenuation properties afford protection against impulsive noise and that the absence of either may be a serious drawback to the **efficiency** of a hearing protector in certain impulsive noise fields.

BIBLIOGRAPHY

Acton, W. I., and Forrest, M. R., (1968) "Hearing Hazard from Small-Bore Weapons," J. Acoust. Soc. Am. 44, 817-818.

American National Standard Method for the Measurement of the Real-Ear Attenuation of Ear Protectors at Threshold, 224.22-1957.

American National Standard Practice for Occupational and Educational Hearing Protection, Z137.1, Working Draft #3, corrected to January 1972.

American National Standards Institute Method for the Measurement of Real-Ear Protection and Physical Attenuation of Hearing Protectors, Preliminary draft #4, corrected to April 1972.

American National Standard Specifications for Audiometers, S3.6-1969.

"Anthropological and Other Data," AMRL-TR 67-203, Army Ground Forces Medical Research Laboratory, Fort Knox, Ky.

Baughn, L., (1971) "The Risk of Hearing Impairment as a Function of Noise Exposure," Proceedings Purdue Noise Conference 1971, available from Dr. M. J. Crocker, School of Mechanical Engineering, Purdue University, Lafayette, Ind.

Canadian Standards Association Standard Z94.2-1965, "Hearing Protectors."

Coles, R. R. A., and Rice, C. G., (1966) "Speech Communications Effects and Temporary Threshold Shift Reduction Provided by VSIR and Selectone-K Earplugs Under Conditions of High Intensity Impulsive Noise," J. Sound and Vibration 4,156-171.

Creston, J. E., (1965) "Noise Induced Hearing Loss," The American Riieman, December, 34-36.

Fairbanks, D. N. F., (1971) "Are You Shooting Your Hearing?" Outdoor Life, October, 57.

Gifford, E. C., Provost, J. R., and Lazo, F. (1965) "Anthropometry of Naval Aviators—1964," NAEC-ACEL-533, AD 626322.

Hertzberg, H. T. E., et al., (1954) "Anthropometry of Flying Personnel—1950," Air Research and Development Command, Wright Patterson Air Force Base, Ohio, WADC-TR 52-231·1950.

Jacobson, B., Dyer, E. M., and Marone, R. J., (1962) "Effectiveness of the VSIR Ear Plug with Impulse Pressures up to 8 psi," U.S. Army Technical Memorandum 1-63, Human Engineering Laboratories, Aberdeen Proving Ground, Md., AD 401212.

Military Standard, "Aural Protector, Sound," MIL-STD-1431, Septembers, 1969, U.S. Dept. of Defense.

Military Specification, "Protector, Sound, Aural," MIL-P-38268B, March 25, 1971, U.S. Dept. of Defense.

Ward, D. W., "Proposed Damage-Risk Criterion for Impulse Noise (Gunfire)," (U) (July 1968) NAS-NRC Committee on Hearing, Bioacoustics, and Biomechanics. Working Group 57.

U. S. GOVERNMENT PRINTING OFFICE : 1973 O 498-356

OTHER PUBLICATIONS OF THE LAW ENFORCEMENT STANDARDS PROGRAM*

Standards

NILECJ-STD-0101.00, March 1972, Ballistic Resistance of Police Body Armor (Stock No. 2700-0155; Price 25 cents).

Reports

LESP-RPT-0201.00, May 1972, Batteries Used with Law Enforcement Communications Equipment – Comparison and Performance Characteristics (Stock No. 2700-0156; Price 50 cents).

LESP-RPT-0501.00, May 1972, Emergency Vehicle Warning Devices – Interim Review of the State-of-the-Art Relative to Performance Standards.

***Please order publications for which a price is indicated by tiile and stock number, and enclose remittance payable to the Superintendent of Documents. Government Printing Office, Washington, D.C. 20402. Single copies may be obtained from the National Criminal Justice Reference Service, Law Enforcement Assistance Administration. U.S. Department of Justice, Washington, D.C. 20530.**

U.S. DEPARTMENT OF JUSTICE
LAW ENFORCEMENT ASSISTANCE ADMINISTRATION
WASHINGTON. D.C. 20530

OFFICIAL BUSINESS

PENALTY FOR PRIVATE USE. $300

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF JUSTICE

JUS-436