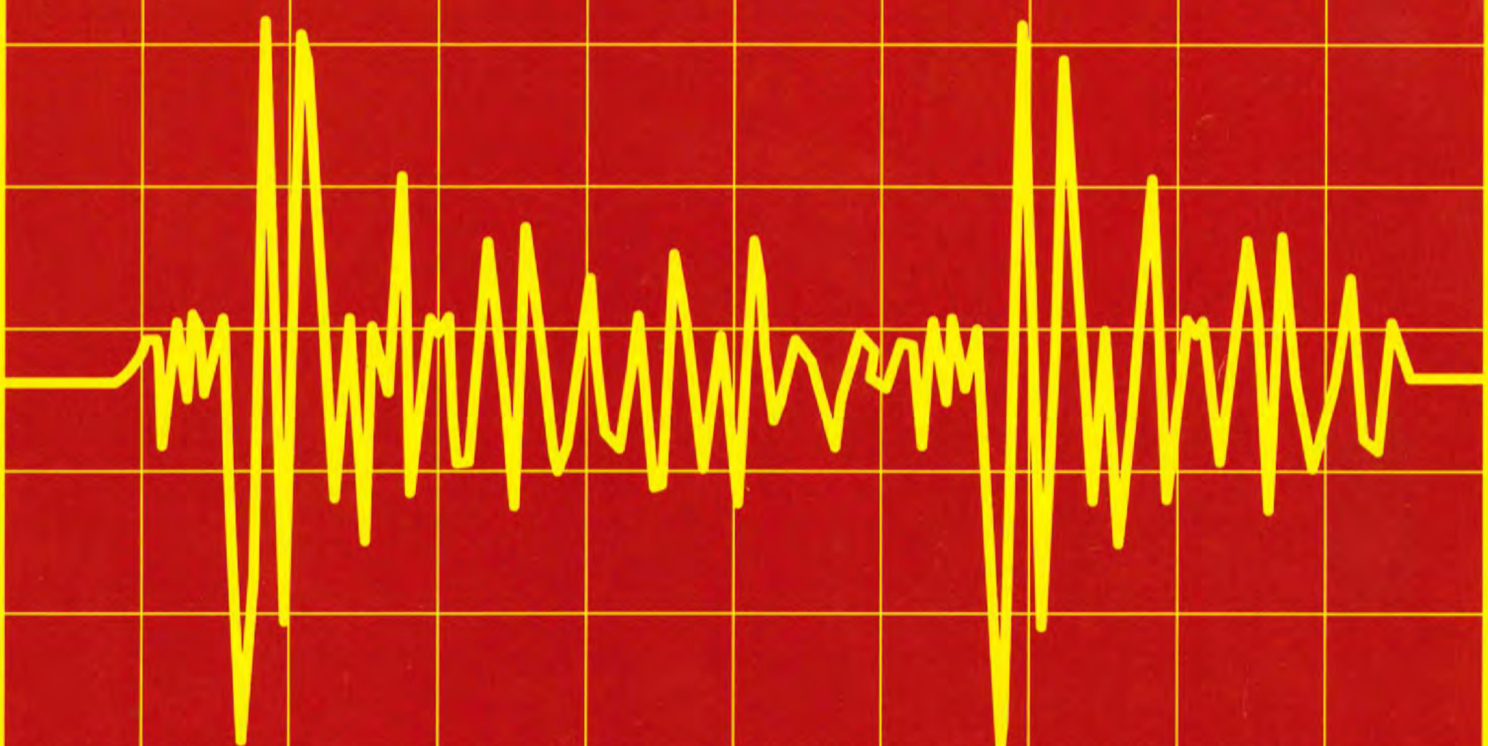
NIOSH Publications on Noise and Hearing



U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health

NIOSH PUBLICATIONS ON NOISE AND HEARING

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer
4676 Columbia Parkway
Cincinnati, Ohio 45226

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INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) has assembled this document in response to an increasing number of requests regarding noise in the workplace. The references cited describe the results of research conducted or funded by NIOSH.

This publication is divided into two parts. The first part contains the list of NIOSH documents on noise and hearing arranged by type of publication. These are listed in separate sections and include numbered publications; contract reports; grant reports; hazard evaluations and technical assistance reports; industrywide study reports; control technology reports; journal articles, book chapters, and presentations; and miscellaneous reports. A brief description of each type of document precedes the listing in that section.

The second part includes full-text or abstracted copies of selected references listed in part one. These references include NIOSH congressional and regulatory testimony, results of NIOSH research, and NIOSH recommendations on current and future issues concerning workplace exposure to noise.

Most items listed in the first part of the publication are NOT available from NIOSH, and must be obtained through a university or public library, or purchased from the National Technical Information Service (NTIS). Order numbers and prices for paper copies are provided for each item. Microfiche copies may also be available from NTIS; prices and availability for microfiche should be confirmed with NTIS before ordering. The NTIS address and telephone number is listed on the NTIS order form included at the back of this publication. Availability and prices are subject to change without notice.

NIOSH BIBLIOGRAPHY - OCCUPATIONAL NOISE AND HEARING

NIOSH NUMBERED PUBLICATIONS document the results of NIOSH research. Included in this category are Criteria Documents, Current Intelligence Bulletins, Alerts, Health and Safety Guides, technical reports of scientific investigations, compilations of data, work-related booklets, symposium and conference proceedings, and NIOSH administrative and management reports.

A Practical Guide to Effective Hearing Conservation Programs in the Workplace.
NIOSH PUB NO: 90-120. 66 pp.
NTIS NO: PB91-152744 $17.00
(An abstract of this publication is contained in part two of this publication.)

Compendium of Materials for Noise Control (2nd Edition).
NIOSH PUB NO: 80-116. 380 pp.
NTIS NO: PB85-177152 $39.00

Criteria for a Recommended Standard: Occupational Exposure to Noise.
NIOSH PUB NO: 73-11001. 154 pp.
NTIS NO: PB-213463 $23.00
(An abstract of this publication is contained in part two of this publication.)

Effects of Noise on Non-Auditory Sensory Functions and Performance.
NIOSH PUB NO: 76-176. 138 pp.
NTIS NO: PB-266247 $23.00

A Field Investigation of Noise Reduction Afforded by Insert-Type Hearing Protectors.
NIOSH PUB NO: 79-115. 51 pp.
NTIS NO: PB-299319 $17.00

A Guide to the Work-Relatedness of Disease (Revised).
NIOSH PUB NO: 79-116. 266 pp.
NTIS NO: PB-298561 $31.00

The Industrial Environment: Its Evaluation and Control, 1973.
NIOSH PUB NO: 74-117. 719 pp.
NTIS NO: PB88-240106 $67.00

Industrial Noise Control Manual (Revised).
NIOSH PUB NO: 79-117. 353 pp.
NTIS NO: PB-297534 $39.00

List of Personal Hearing Protectors and Attenuation Data.
NIOSH PUB NO: 76-120. 44 pp.
NTIS NO: PB-267461 $15.00

NIOSH Proposed National Strategies for the Prevention of Leading Work-Related Diseases and Injuries -- Noise-Induced Hearing Loss, 1988.
NIOSH PUB NO: 89-135. 18 pp.
NTIS NO: PB90-168758 $15.00
(A copy of this report is contained in part two of this publication.)

Occupational Diseases: A Guide to Their Recognition (Revised).
NIOSH PUB NO: 77-181. 619 pp.
NTIS NO: PB83-129528 $60.00
(A copy of the section on noise is contained in part two of this publication.)

Occupational Noise and Hearing: 1968-1972.
NIOSH PUB NO: 74-116. 51 pp.
NTIS NO: PB-232284 $17.00

Occupational Safety and Health Symposia - 1975.
NIOSH PUB NO: 76-136. 238 pp.
NTIS NO: PB-266445 $31.00

Prevalence of Middle Ear Disorders in Coal Miners.
NIOSH PUB NO: 81-101. 39 pp.
NTIS NO: PB81-237844 $15.00

A Real-Ear Field Method for the Measurement of the Noise Attenuation of Insert-Type Hearing Protectors.
NIOSH PUB NO: 76-181. 171 pp.
NTIS NO: PB-267419 $23.00

A Report on the Performance of Personal Noise Dosimeters.
NIOSH PUB NO: 78-186. 165 pp.
NTIS NO: PB80-176084 $23.00

Survey of Hearing Conservation Programs in Industry.
NIOSH PUB NO: 75-178. 136 pp.
NTIS NO: PB-274235 $23.00

Survey of Hearing Loss in the Coal Mining Industry.
NIOSH PUB NO: 76-172. 145 pp.
NTIS NO: PB-271811 $23.00

CONTRACT REPORTS are generated primarily from a contractual agreement between NIOSH and a non-governmental organization. They typically describe scientific research conducted by that organization for NIOSH.

Advanced Industrial Hygiene Engineering - 552 - Student Manual, Revised June 1986.
CONTRACT NO: 210-75-0076. 919 pp.
NTIS NO: PB87-229621 $81.00

Control Technology Assessment in the Paper and Pulp Industry, April 1983.
CONTRACT NO: 210-79-0008. 974 pp.
NTIS NO: PB84-151927 $81.00

Effects of a Company Hearing Conservation Program on Extra-Auditory Disturbances in Workers, 1975.
CONTRACT NO: 099-74-0028. 380 pp.
NTIS NO: PB82-151853 $39.00

Effects of Non-Occupational Noise Exposure on a Young Adult Population, 1972.
CONTRACT NO: 099-71-0052. 39 pp.
NTIS NO: PB82-230129 $15.00

Engineering Health Hazard Control Technology for Coal Gasification and Liquefaction Processes - Final Report, 1983.
CONTRACT NO: 210-78-0084. 105 pp.
NTIS NO: PB90-14276 $23.00

An Exploratory Study of Physiologic and Subjective Reactions Evoked by Aversive and Non-Aversive Sounds, Final Report, 1972.
CONTRACT NO: 099-71-0039. 124 pp.
NTIS NO: PB85-220671 $23.00

Identification of Occupational Impact/Impulsive Noise Sources, 1976.
CONTRACT NO: 210-75-0068. 293 pp.
NTIS NO: PB86-109139 $31.00

Industrial Hygiene Characterization and Aerobiology of Resource Recovery Systems - Final Report, 1982.
CONTRACT NO: 210-79-0013. 396 pp.
NTIS NO: PB85-207884 $39.00

Industrial Noise and Worker Medical, Absence, and Accident Records, 1972.
CONTRACT NO: 099-71-0006. 326 pp.
NTIS NO: PB82-166315 $39.00

Occupational Health Assessment of Resource Recovery Energy Industries Municipal Solid Waste-to-Solid Fuel Processing Facilities, 1979.
CONTRACT NO: 210-77-0031. 201 pp.
NTIS NO: PB82-150376 $31.00

Occupational Health Assessment of the Geothermal Hydrothermal Convection Industry, 1979.
CONTRACT NO: 210-77-0031. 76 pp.
NTIS NO: PB82-162595 $17.00

Permanent Threshold Shift and Temporary Threshold Shift Resulting from Industrial Noise Exposure, 1975.
CONTRACT NO: 099-72-0032. 65 pp.
NTIS NO: PB82-237736 $17.00

Planning Report for an Epidemiological Study of Agricultural Workers Exposed to Noise, 1975.
CONTRACT NO: 099-74-0110. 34 pp.
NTIS NO: PB83-234989 $15.00

Recognition or Occupational Health Hazards - 510 Course Manual, Vol. I, 1974.
CONTRACT NO: 099-74-0032. 537 pp.
NTIS NO: PB85-107662 $53.00

Safety Information Profile, Aircraft Ground Support - Equipment Operation, 1979.
CONTRACT NO: 210-78-0130. 80 pp.
NTIS NO: PB84-153832 $17.00

Safety Information Profile, Glass Bottle Manufacturing, 1979.
CONTRACT NO: 210-81-0130. 52 pp.
NTIS NO: PB84-153832 $17.00

A Second Field Investigation of Noise Reduction Afforded by Insert-Type Hearing Protectors, 1982.
CONTRACT NO: 210-81-3001. 60 pp.
NTIS NO: PB83-138768 $17.00

So You Work in a Foundry. Book I - Pattern Shop, Core Room Molding Shop and Sandhandling Department, 1975.
CONTRACT NO: 210-75-0057. 30 pp.
NTIS NO: PB83-115790 $15.00

So You Work in a Foundry. Book II - Melting and Pouring, 1976.
CONTRACT NO: 210-75-0057. 47 pp.
NTIS NO: PB83-115808 $15.00

GRANT REPORTS are generated primarily from an agreement between NIOSH and a non-governmental organization. They typically describe scientific research conducted by that organization for NIOSH. Grant reports may be published either as final reports available from NTIS or as journal articles. Bibliographic information is provided to permit retrieval of the latter from public or university libraries.

Acoustic Environmental Control, Final Report. February 1977.
GRT NO: T01EC00118. 6 pp.
NTIS NO: PB89-220982 $11.00

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GRT NO: R01OH00705. 31 pp.
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Asymptotic Threshold Shift from Impulse Noise. Hamernik R, Henderson D [1982]. In: New Perspectives on Noise-Induced Hearing Loss, Hamernik R, Henderson D, Salvi R (Eds.), New York, NY: Raven Press, pp. 265-281.
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Spinning Frame Noise Sources. Stewart N, Emerson P, Bailey J [1976]. Journal for the Engineering Industry 98(3):840-844.
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The **HAZARD EVALUATIONS AND TECHNICAL ASSISTANCE (HETA)** Program of NIOSH provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational hazards and to prevent related trauma or disease. Reports resulting from this Program may be identified as Health Hazard Evaluations (HHE), Technical Assistance (TA) reports, Government Hazard Evaluations (GHE), or HETAs. Please note that each report discusses the conditions only at the specific worksite evaluated.

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NTIS NO : PB-229081 $15.00

Alabama Oxygen, Inc., Bessemer, AL, 1980.
HHE NO : 80-213-759. 12 pp.
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Amax Aluminum Mill Products, Riverside, CA, 1974.
HHE NO : 73-187-151. 8 pp.
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AMF Head Division, Boulder, CO, July 1986.
HETA NO: 85-256-1716. 16 pp.
NTIS NO : PB87-161287 $15.00

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NTIS NO : PB-232729 $15.00

Big Dry Creek Plant, Westminster, CO, April 1985.
HETA NO: 84-307-1581. 15 pp.
NTIS NO : PB86-132792 $15.00

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HHE NO : 81-293-983. 10 pp.
NTIS NO : PB83-161208 $11.00

C.F. and I. Steel Corp., Pueblo, CO, 1981.
HHE NO : 80-198-824. 8 pp.
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HETA NO: 86-437-1818. 16 pp.
NTIS NO : PB88-153317 $11.00

Chicago and North Western Railway Diesel Shop, Oelwein, IA, 1974.
HHE NO : 72-097-135. 19 pp.
NTIS NO : PB-246442 $15.00

Cincinnati Water Treatment Plant, Cincinnati, OH, 1981.
HHE NO : 81-160-918. 9 pp.
NTIS NO : PB83-102731 $11.00

City of Ames Municipal Power Plant, Ames, IA, May 1988.
HETA NO: 86-422-1891. 60 pp.
NTIS NO : PB89-106561 $17.00

Cotton Gins, Colorado River Indian Reservation, Poston and Parker, AZ, 1980.
HHE NO : 80-245-1210. 41 pp.
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Denver Laundry and Dry Cleaning, Denver, CO, July 1985.
HETA NO: 84-340-1606. 14 pp.
NTIS NO : PB86-145349 $15.00

Denver Water Department, Denver, CO, January 1986.
HETA NO: 84-257-1650. 16 pp.
NTIS NO : PB86-221280 $15.00

Detroit Canada Tunnel, Detroit, MI, 1980.
HHE NO : 79-000-025. 12 pp.
NTIS NO : PB80-192065 $15.00

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HHE NO : 79-026-614. 15 pp.
NTIS NO : PB80-163116 $15.00

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HETA NO: 84-028-1517. 16 pp.
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HETA NO: 82-270-1238. 18 pp.
NTIS NO : PB84-172741 $15.00

Dubois Chemical Company, Sharonville, OH, July 1987.
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Dyna-Con Packaging Corp., Hamilton, OH, 1972.
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Empire Detroit Steel Co., New Boston, OH, 1972.
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The Evening News, Southbridge, MA, March 1982.
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NTIS NO : PB89-230544 $15.00

FMC Corporation, San Jose, CA, September 1985.
HETA NO: 84-368-1624. 26 pp.
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Ford Motor Co., Rouge Plant, Dearborn, MI, 1972.
HHE NO : 71-006-001. 15 pp.
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Fortune Industries, Inc., Chelsea, MI, 1973.
HHE NO : 72-043-057. 22 pp.
NTIS NO : PB-229123 $15.00

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HETA NO: 81-340-1020. 8 pp.
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HETA NO: 81-197-995. 9 pp.
NTIS NO : PB82-187055 $11.00

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HETA NO: 84-493-1583. 21 pp.
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HHE NO : 80-164-943. 10 pp.
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Industrial Plastics, Valley City, OH, April 1982.
HETA NO: 81-029-1088. 44 pp.
NTIS NO : PB83-198390 $15.00

Ingersoll Rand, Foundry Division, Athens, PA, 1975.
HHE NO : 73-101-190. 11 pp.
NTIS NO : PB-249370 $15.00

Inmos Corp., Colorado Springs, CO, May 1982.
HETA NO: 81-319-1114. 27 pp.
NTIS NO : PB84-140664 $15.00

International Association of Fire Fighters, Cincinnati, OH, May 1988.
HETA NO: 84-454-1890. 22 pp.
NTIS NO : PB89-106553 $15.00

James River Power Plant, City Utilities, Springfield, MO, April 1984.
HETA NO: 82-119-1454. 40 pp.
NTIS NO : PB85-184133 $15.00

Jeffery Bigelow Design Group, Inc., Washington, DC, 1976.
HHE NO : 76-092-363. 20 pp.
NTIS NO : PB-273913 $15.00

Kawecki Berylco Industries, Inc., Reading, PA, 1976.
HHE NO : 75-087-280. 23 pp.
NTIS NO : PB89-161251 $15.00

Keller Aluminum Furniture of Indiana, Linton, IN, January 1977.
HHE NO : 77-027-437. 27 pp.
NTIS NO : PB89-137434 $15.00

L.R.I. Industries, Chelsea, MI, 1980.
HHE NO : 79-100-665. 14 pp.
NTIS NO : PB80-174790 $15.00

Lance Corp., Hudson, MA, 1980.
HHE NO : 79-132-673. 17 pp.
NTIS NO : PB80-192073 $15.00

Lincoln Medical and Mental Health Center, Bronx, NY, February 1981.
HETA NO: 81-066-882. 9 pp.
NTIS NO : PB82-162249 $11.00

Midwest Steel Division, National Steel Corp., Portage, IN, 1972.
HHE NO : 71-001-004. 17 pp.
NTIS NO : PB-229076 $15.00

Miller Thermal Technologies, Inc., Appleton, WI, January 1989.
HETA NO: 88-135-1945. 50 pp.
NTIS NO : PB89-188031 $15.00

Ministry of Health - St. Lucia, St. Lucia, West Indies, August 1988.
HETA NO: 87-413-1921. 112 pp.
NTIS NO : PB89-152888 $23.00

Modern Industrial Plastics Division, Duriron Co., Dayton, OH, 1973.
HHE NO : 72-029-028. 30 pp.
NTIS NO : PB-229167 $15.00

Mystic Seaport, Mystic, CT, May 1985.
HETA NO: 85-132-1598. 18 pp.
NTIS NO : PB86-135431 $15.00

N.L. Industries, Inc., Atlanta, GA, 1972.
HHE NO : 71-019-008. 13 pp.
NTIS NO : PB-229191 $15.00

N.L. Industries, Inc., Titanium Pigmant Division, St. Louis, MO, 1972.
HHE NO : 72-088-068. 13 pp.
NTIS NO : PB-229604 $15.00

Newburgh Fire Department, Newburgh, NY, February 1982.
HETA NO: 81-059-1045. 39 pp.
NTIS NO : PB83-202101 $15.00

New York Fire Department, New York, NY, July 1985.
HETA NO: 81-459-1603. 14 pp.
NTIS NO : PB86-144680 $15.00

NIOSH Facilities, Rockville, MD, November 1977.
TA NO : 77-000-046. 6 pp.
NTIS NO : PB82-157736 $11.00

Peace Bridge, Buffalo, NY, and Rainbow Bridge, Niagara, NY, April 1980.
TA NO : 79-9000-008. 14 pp.
NTIS NO : PB80-211790 $15.00

Portec, Inc., Paducah, KY, February-March, 1978.
TA NO : 78-000-021. 24 pp.
NTIS NO : PB82-187881 $15.00

Publishers Paper Co., Newberg, OR, April 1981.
HETA NO: 81-090-997. 10 pp.
NTIS NO : PB82-187386 $11.00

PVC Container Corp., Eatontown, NJ, August 1982.
HETA NO: 80-104-1158. 19 pp.
NTIS NO : PB84-150614 $15.00

Raybestos-Manhattan, Inc., Crawfordsville, IN, 1972.
HHE NO : 71-021-022. 19 pp.
NTIS NO : PB-229119 $15.00

Rollins Environmental Services, Baton Rouge, LA, February 1982.
HETA NO: 81-037-1055. 52 pp.
NTIS NO : PB83-214254 $17.00

Siemens Components, Inc., Broomfield, CO, March 1984.
HETA NO: 83-269-1430. 19 pp.
NTIS NO : PB85-180313 $15.00

Siouxpreme Egg Products, Sioux Center, IA, January 1986.
HETA NO: 84-163-1657. 43 pp.
NTIS NO : PB86-223013 $15.00

Southern Bell Telephone Co., Hollywood, FL, January 1981.
HHE NO : 81-086-837. 10 pp.
NTIS NO : PB83-102939 $11.00

Stanley Aviation Corp., Denver, CO, September 1984.
HETA NO: 84-286-1512. 9 pp.
NTIS NO : PB85-220283 $11.00

Sun Products Corp., Barberton, OH, 1973.
HHE NO : 72-012-026. 19 pp.
NTIS NO : PB-229166 $15.00

Technology Products, Inc., Longmont, CO, July 1980.
HHE NO : 80-152-774. 10 pp.
NTIS NO : PB83-157891 $11.00

Technology Products, Inc., Longmont, CO, November 1980.
HHE NO : 80-231-835. 10 pp.
NTIS NO : PB83-105361 $11.00

Texas Boot Co., Hartsville, TN, August and October, 1978.
TA NO : 78-058-864. 34 pp.
NTIS NO : PB82-215369 $15.00

Texas International Airlines, Denver, CO, November 1982.
HETA NO: 82-316-1230. 14 pp.
NTIS NO : PB84-172758 $15.00

U.S. Army Research Office, Research Triangle Park, NC, September 1982.
HETA NO: 82-136-1175. 16 pp.
NTIS NO : PB84-150259 $15.00

U.S. Border Crossing Stations, El Paso, TX, August 1979.
TA NO : 79-027-979. 17 pp.
NTIS NO : PB83-161216 $15.00

U.S. Border Crossing Stations, Laredo, TX, September-October, 1979.
TA NO : 79-026-978. 17 pp.
NTIS NO : PB83-158519 $15.00

U.S. Bulk Mail Center, St. Louis, MO, March 1982.
HETA NO: 81-456-1075. 11 pp.
NTIS NO : PB83-199455 $15.00

U.S. District Court of Columbia, Indoor Firing Range, Washington, DC, 1980.
TA NO : 80-000-034. 11 pp.
NTIS NO : PB80-211485 $15.00

U.S. Environmental Protection Agency, Cincinnati, OH, February 1988.
HETA NO: 88-095-0000. 19 pp.
NTIS NO : PB88-204607 $15.00

U.S. Postal Service, Washington Bulk Mail Center, Washington, DC, May 1982.
HETA NO: 81-297-1116. 9 pp.
NTIS NO : PB84-139641 $11.00

Valley Comprehensive Community Mental Health Center, Morgantown, WV, September 1980.
HHE NO : 80-000-225. 15 pp.
NTIS NO : PB82-184532 $15.00

West Virginia Department of Highways, Charleston, WV, February 1987.
HETA NO: 86-191-1836. 24 pp.
NTIS NO : PB88-162698 $15.00

Western Gear Corp., Flight Division, Jamestown, ND, June 1978.
HHE NO : 78-076-548. 21 pp.
NTIS NO : PB81-150443 $15.00

INDUSTRYWIDE STUDY REPORTS represent the results of industrial hygiene field studies that assess whether specific occupational exposures of particular workers are associated with adverse health effects. The majority of these reports document information obtained during brief 1- to 2-day walk-through surveys at plant sites to evaluate their suitability for industrywide studies. In-depth survey reports present detailed exposure information collected during a 1-week survey at a plant site.

Comprehensive Industrial Hygiene Survey Report, Koehler Co., Camp Kroft, Spartanburg, SC, October 16-20, 1972.
IWS NO: IW/035.14. 41 pp.
NTIS NO: PB81-229890 $15.00

Evaluation of Environmental Hazards Associated with Metal Foundries Located in the State of Utah, November and December 1968.
IWS NO: IW/040.16M. 4 pp.
NTIS NO: PB89-122923 $ 8.00

Fibrous Glass Dust and Industrial Hygiene Survey Report, Pittsburgh Plate Glass Industries, Shelbyville, IN, August 28-September 1, 1972.
IWS NO: IW/035.20. 54 pp.
NTIS NO: PB81-241861 $17.00

Fibrous Glass Dust and Industrial Hygiene Survey Report, General Electric Appliance Park, Louisville, KY, November 8-9, 1972.
IWS NO: IW/035.12. 27 pp.
NTIS NO: PB82-108200 $15.00

Formaldehyde Exposure Characterization in Garment Manufacturing Plants: A Composite Summary of Three In-Depth Industrial Hygiene Surveys, January 1987.
IWS NO: IW/125.26. 51 pp.
NTIS NO: PB87-205019 $17.00

Hanna Nickel Smelting Co., Riddle, OR, October 1967.
IWS NO: IW/063.11B. 14 pp.
NTIS NO: PB88-224241 $15.00

In-Depth Industrial Hygiene Report of the American Enka Co., March 6-14 and March 26-April 13, 1979.
IWS NO: IW/075.14.20. 80 pp.
NTIS NO: PB83-221689 $17.00

In-Depth Industrial Hygiene Survey Report, Arrow Shirt Co., Atlanta, GA, October 26, 1983.
IWS NO: IW/125.12B. 36 pp.
NTIS NO: PB84-181940 $15.00

Industrial Hygiene Study of Polyurethane Foam Insulation Application Activities, Thermal Acoustic Foam Insulation Inc., Columbia, MD, November 19-20, 1979.
IWS NO: IW/069.15. 26 pp.
NTIS NO: PB81-239899 $15.00

Industrial Hygiene Survey Report, Amax Nickel Refining Co., Inc., Braithwaite, LA, February 8, 1977.
IWS NO: IW/063.13. 23 pp.
NTIS NO: PB83-106369 $15.00

Industrial Hygiene Survey Report, B.F. Goodrich Chemical Co., Polyvinyl Chloride Operations, Pedricktown, NJ, August 5-9, 1974.
IWS NO: IW/049.17. 18 pp.
NTIS NO: PB81-228959 $15.00

Industrial Hygiene Survey Report, Celotex Corp., Pittston, PA, December 14-17, 1976.
IWS NO: IW/035.31. 87 pp.
NTIS NO: PB82-107103 $17.00

Industrial Hygiene Survey Report, Urea Formaldehyde Foam Insulation Manufacturing, C.P. Chemical Co., Inc., White Plains, NY, March 3-4, 1980.
IWS NO: IW/069.16. 27 pp.
NTIS NO: PB81-241812 $15.00

Industrial Hygiene Survey Report, Engelhard Minerals and Chemicals Corp., Attapulgus, GA, March 22-26, 1976.
IWS NO: IW/052.10. 80 pp.
NTIS NO: PB89-100960 $17.00

Industrial Hygiene Survey Report, Federated Metals Corp., Whiting, IN, March 9-10, 1972.
IWS NO: IW/056.17B. 9 pp.
NTIS NO: PB81-230054 $11.00

Industrial Hygiene Survey Report, Great Western Limestone Mine, Crushing and Screening Mill, Horse Creek, WY, February 5, 1970.
IWS NO: IW/030.27. 9 pp.
NTIS NO: PB81-241739 $11.00

Industrial Hygiene Survey Report, Hitco, Atlanta, GA, August 7-9, 1973.
IWS NO: IW/035.25. 46 pp.
NTIS NO: PB81-224677 $15.00

Industrial Hygiene Survey Report, Johns-Manville Mineral Wool Fiber Facility, Alexandria, IN, April 11-15, 1975.
IWS NO: IW/035.26. 117 pp.
NTIS NO: PB82-116070 $23.00

Industrial Hygiene Survey Report, Owens-Corning Fiberglas, Kansas City, KS, January 29-February 2, 1973.
IWS NO: IW/035.16. 45 pp.
NTIS NO: PB81-241697 $15.00

Industrial Hygiene Survey Report, Pacor, Inc., Philadelphia, PA, August 10-11, 1977.
IWS NO: IW/035.37. 20 pp.
NTIS NO: PB81-241770 $15.00

Industrial Hygiene Survey Report, Urea Formaldehyde Foam Insulation Application Activities, Pel Foam Insulation, Inc., Rockville, MD, September 17-18 and December 6, 10-12, 1979.
IWS NO: IW/069.11. 40 pp.
NTIS NO: PB82-109943 $15.00

Industrial Hygiene Survey Report, Urea Formaldehyde Foam Insulation Manufacturing, Rapco Foam, Inc., Florence, SD, August 28-30 and September 25-27, 1979.
IWS NO: IW/069.10. 39 pp.
NTIS NO: PB81-228868. $15.00

Industrial Hygiene Survey Report, Reynolds Metals Listerhill Reduction Plant, Sheffield, AL, February 12-16, 1973.
IWS NO: IW/038.16A. 60 pp.
NTIS NO: PB81-224735 $17.00

Industrial Hygiene Survey Report, Reynolds Metals, Jones Mill Aluminum Reduction Plant, Jones Mill, AR, March 19-23, 1973.
IWS NO: IW/038.17. 61 pp.
NTIS NO: PB82-110016 $17.00

Industrial Hygiene Survey Report, Rockwool Industries, Inc., Pueblo, CO, September 20-25, 1976.
IWS NO: IW/035.30. 81 pp.
NTIS NO: PB82-179797 $17.00

Industrial Hygiene Survey Report, Union Carbide Corp., Polyvinyl Chloride Operations, South Charleston, WV, June 10-19, 1974.
IWS NO: IW/049.16. 28 pp.
NTIS NO: PB82-150939 $15.00

Industrial Hygiene Survey Report, Urea Formaldehyde Foam Insulation Application Activities, Thermoseal of Maryland, Inc., Laurel, MD, November 26-30, 1979.
IWS NO: IW/069.14. 33 pp.
NTIS NO: PB82-112855 $15.00

Industrial Hygiene Surveys Conducted during FY-1973 in Six Aluminum Plants Located in Northwestern United States.
IWS NO: IW/038.30. 51 pp.
NTIS NO: PB82-216144 $17.00

Industrywide Studies Report of an Industrial Hygiene Survey at the Clermont Sun, Batavia, OH, September 26, 1984 and January 17, 1986.
IWS NO: IW/077.37. 28 pp.
NTIS NO: PB86-237286 $15.00

Industrywide Study Report, In-Depth Survey, Arrow Shirt Co., Lewistown, PA, December 26, 1984.
IWS NO: IW/125.17B. 54 pp.
NTIS NO: PB85-222248 $17.00

Men's Apparel Industrywide Study, Colebrook Mills, Division of Bobbie Brooks, Hialeah, FL, May 15, 1974.
IWS NO: IW/046.45. 3 pp.
NTIS NO: PB83-105312 $ 8.00

Men's Apparel Industrywide Study, Edrick Manufacturing Co., Division of Public Shirt Corp., Columbia, TN, November 1974.
IWS NO: IW/046.21. 4 pp.
NTIS NO: PB82-112806 $ 8.00

Men's Apparel Industrywide Study, F. Jacobson, Inc. (Excello Shirt Co.), Division of Kayser-Roth Corp., Seymour, IN, August 1974.
IWS NO: IW/046.18. 6 pp.
NTIS NO: PB82-112798 $11.00

Men's Apparel Industrywide Study, Gant Shirtmakers, Division of Consolidated Foods, Salisbury, MD, September 1974.
IWS NO: IW/046.19. 2 pp.
NTIS NO: PB82-107186 $ 8.00

Men's Apparel Industrywide Study, Globe Tailoring Co. and Magliano Pants Co., Cincinnati, OH, September 1974.
IWS NO: IW/046.13. 2 pp.
NTIS NO: PB81-229593 $ 8.00

Men's Apparel Industrywide Study, Hampco Apparel Corp., Division of Hampton Industries, Martinsville, VA, October 24, 1974.
IWS NO: IW/046.29. 6 pp.
NTIS NO: PB82-112830 $11.00

Men's Apparel Industrywide Study, Horace Small Manufacturing Co., Nashville, TN, November 1974.
IWS NO: IW/046.26. 5 pp.
NTIS NO: PB82-104498 $ 8.00

Men's Apparel Industrywide Study, Imperial Reading Corp., Subsidiary of Northwest Industries, Inc., Piney Flats, TN, October 23, 1974.
IWS NO: IW/046.37. 9 pp.
NTIS NO: PB82-112848 $11.00

Men's Apparel Industrywide Study, Jay Garment Co., Inc., Clarksville, TN, October 30, 1974.
IWS NO: IW/046.38. 6 pp.
NTIS NO: PB81-229130 $11.00

Men's Apparel Industrywide Study, Lady Manhattan Shirt Co. Division, Manhattan Industries, Inc., Salisbury, MD, September 1974.
IWS NO: IW/046.20. 3 pp.
NTIS NO: PB82-104514 $ 8.00

Men's Apparel Industrywide Study, Lauderdale Garment Corp., Division of Master Trouser Corp., Ripley, TN, November 4, 1974.
IWS NO: IW/046.33. 3 pp.
NTIS NO: PB81-230690 $ 8.00

Men's Apparel Industrywide Study, Levi Strauss and Co., Maryville, TN, October 22, 1974.
IWS NO: IW/046.27. 3 pp.
NTIS NO: PB81-225302 $ 8.00

Men's Apparel Industrywide Study, Levi Strauss and Co., Blackstone, VA, October 25, 1974.
IWS NO: IW/046.30. 8 pp.
NTIS NO: PB88-249388 $11.00

Men's Apparel Industrywide Study, Ralph Edwards Sportswear, Inc., Cape Girardeau, MO, August 16, 1974.
IWS NO: IW/046.40. 4 pp.
NTIS NO: PB81-242745 $ 8.00

Men's Apparel Industrywide Study, Salant and Salant, Parsons, TN, October 31, 1974.
IWS NO: IW/046.32. 3 pp.
NTIS NO: PB82-112715 $ 8.00

Men's Apparel Industrywide Study, Sandy Lee Manufacturing Co., Division of Gordon and Ferguson Co., Menomonie, WI, July 23, 1974.
IWS NO: IW/046.41. 3 pp.
NTIS NO: PB81-242752 $ 8.00

Men's Apparel Industrywide Study, Thorngate Ltd., Division of Hart, Schaffner and Marx, Cape Girardeau, MO, September 1974.
IWS NO: IW/046.25. 4 pp.
NTIS NO: PB82-112822 $ 8.00

Men's Apparel Industrywide Survey Report, Harry I. Siegel Co., Inc., Dixon, TN, October 30, 1974.
IWS NO: IW/046.31. 6 pp.
NTIS NO: PB81-242760 $11.00

Nu Tex Brick Plant, El Paso, TX, May 20, 1965.
IWS NO: IW/030.26. 6 pp.
NTIS NO: PB82-151242 $11.00

Report of Free Silica and Noise Hazard to Workers in Sand and Gravel Crushers and Hot Mix Plants, Idaho, New Mexico, and Oregon, August 1969.
IWS NO: IW/030.22. 12 pp.
NTIS NO: PB82-104456 $15.00

Survey Report, General Motors Assembly Division, Norwood, OH, January 19, 1978.
IWS NO: IW/065.15. 14 pp.
NTIS NO: PB82-108309 $15.00

Survey Report, Metalizing Operation, Rock Island Arsenal, Rock Island, IL, March 13, 1978.
IWS NO: IW/065.14. 12 pp.
NTIS NO: PB82-108291 $15.00

Utah State Division of Health Report of Environmental Study, Backman Foundry and Machine, Provo, UT, November 8 and December 18, 1968.
IWS NO: IW/040.16J. 5 pp.
NTIS NO: PB82-124892 $ 8.00

Utah State Division of Health Report of Environmental Study, Ogden Iron Works, Ogden, UT, November 13 and December 19, 1968.
IWS NO: IW/040.16K. 7 pp.
NTIS NO: PB82-181249 $11.00

Utah State Division of Health, Report of Environment Study, May Foundry and Machine Co., Salt Lake City, UT, December 16-17, and 19, 1968.
IWS NO: IW/040.16L. 5 pp.
NTIS NO: PB82-101775 $ 8.00

Walk-Through Survey Report, American Enka Company, Lowland, TN, June 1-2, 1977.
IWS NO: IW/075.14.10. 6 pp.
NTIS NO: PB-278791 $11.00

CONTROL TECHNOLOGY REPORTS represent the results of field study surveys that evaluate health hazard control systems. The field studies begin with walk-through surveys which provide preliminary evaluations of control systems to identify those worthy of in-depth study. In-depth surveys are performed to provide a detailed evaluation of selected control systems.

Control Technology Assessment for Coal Gasification and Liquefaction Processes, Caterpillar Tractor Corp., York, PA, August 28, 1980 and May 7, 1981.
CT NO: CT/119.22A. 69 pp.
NTIS NO: PB84-183995 $17.00

Control Technology Assessment for Coal Gasification and Liquefaction Processes, Combustion Engineering Process Development Unit, Windsor, CT, January 18, 1979 and March 8, 1979.
CT NO: CT/119.11A. 48 pp.
NTIS NO: PB84-186014 $15.00

Control Technology Assessment, General Refactories Company, Hitchens, KY, September 21, 1982, Preliminary Report.
CT NO: CT/110.18A. 4 pp.
NTIS NO: PB86-226883 $ 8.00

Control Technology Assessment, Stark Ceramics Inc., Canton, OH, September 27, 1982, Preliminary Report.
CT NO: CT/110.30A. 4 pp.
NTIS NO: PB86-223351 $ 8.00

Control Technology for the Ceramics Industry, American Standard Corp., Wauregan, CT, July 19, 1982, Preliminary Survey Report.
CT NO: CT/110.28A. 7 pp.
NTIS NO: PB86-223666 $11.00

Control Technology, Whitacre-Greer Fireproofing Company, Waynesburg, OH, September 28, 1982, Preliminary Report.
CT NO: CT/110.21A. 4 pp.
NTIS NO: PB86-225679 $ 8.00

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Baier E [1977]. NIOSH testimony before the Subcommittee on Compensation, Health and Safety, House Committee on Education and Labor, October 4.
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Dunn D [1987]. Cochlear morphology associated with overexposure to noise. Hearsay, Spring, pp. 22-29.

Dunn D [1988]. Making the commitment to effective hearing conservation. Applied Industrial Hygiene 3(9):F16&F18.

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Finklea J [1975]. NIOSH statement before the DOL, at the Occupational Safety and Health Administration's Public Hearing on the Proposed Standard for Occupational Noise, June 23.
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Finklea J, Cohen A, Henderson T [1975]. NIOSH statement before the Government Regulation Subcommittee, Senate Small Business Committee, July 23.
(A copy of this statement is contained in part two of this publication.)

Flesch J, Tubbs R, Carpenter J [1986]. Siren noise. Emergency 18(10):42.

Franks J, Davis R, Kreig E [1989]. Analysis of a hearing conservation program database: factors other than workplace noise. Ear and Hearing 10(5):273-280.

Franks J [1988]. Management of hearing conservation data with microcomputers. In: Hearing Conservation in Industry, Schools, and the Military, Lipscomb D (Ed.), Boston, MA: Little, Brown and Co., pp. 113-143.

Franks J, Merry C, Engel D [1989]. Noise reducing muffs for audiometry. Hearing Instruments 40(11):29-36.

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Lempert B [1984]. Compendium of hearing protection devices. Sound and Vibration 18(5):26-39.
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MISCELLANEOUS REPORTS include documents that do not fit into one of the preceding seven sections.

Applied Industrial Hygiene - 549, December 1980. 325 pp.
NTIS NO: PB85-238996 $39.00

Compendium of Hearing Protection Devices, May 1984. 55 pp.
NTIS NO: PB84-237288 $17.00

Control of the Occupational Environment, Instructor's Manual, September 1980. 76 pp.
NTIS NO: PB85-241545 $17.00

Environmental Evaluation of Stress and Hypertension in Municipal Bus Drivers, October 1985. 36 pp.
NTIS NO: PB86-144763 $15.00

Health and Safety Survey of the George Banta Printing Company, Preliminary Report, August 1974. 76 pp.
NTIS NO: PB83-21411627 $17.00

Impulse Contribution to Total Worker Noise Dose, 1983. 20 pp.
NTIS NO: PB84-241884 $15.00

Index of Signs and Symptoms of Industrial Diseases, April 1980. 55 pp.
NTIS NO: PB83-103374 $17.00

Industrial Hygiene Engineering and Control, Introduction - 552, Student Manual (Section 1), November 1978. 114 pp.
NTIS NO: PB85-178200 $23.00

Industrial Hygiene Review Manual, September 1982. 276 pp.
NTIS NO: PB85-103836 $31.00

Industrial Hygiene Engineering and Control, Sound - 552, Student Manual (Section 4), November 1978. 175 pp.
NTIS NO: PB85-178226 $23.00

Industrial Sound Level Meter Acoustical Calibrator Accuracy Test, 1977. 120 pp.
NTIS NO: PB-262621 $23.00

Industrial Sound Level Meter Amplifier Overload Distortion Test, 1976. 26 pp.
NTIS NO: PB-266264 $15.00

Industrial Sound Level Meter Magnetic Field Sensitivity Test, 1976. 16 pp.
NTIS NO: PB-259623 $15.00

Industrial Sound Level Meter Scale of the Indicating Instrument Test, 1976. 16 pp.
NTIS NO: PB-257905 $15.00

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NTIS NO: PB-250816 $15.00

Industrial Sound Level Meter Square Law Characteristic Test, 1975. 37 pp.
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Sound Survey, Taft Sanitary Engineering Center Electric Shop, October 1964. 9 pp.
NTIS NO: PB85-220044 $11.00

Study of Noise and Hearing in the Papermaking Industry, March 1983. 105 pp.
NTIS NO: PB83-207712 $23.00

Technical Evaluation of Pneumatic Tool Noise, June 1978. 79 pp.
NTIS NO: PB83-117663 $17.00

NIOSH

A Recommended Standard for Occupational Exposure to.....

Noise

Section 20(a)(3) of the Occupational Safety and Health Act directs that the Secretary of Health, Education, and Welfare, on the basis of such research, demonstrations, and experiments, and any other information available to him, shall develop criteria dealing with toxic materials and harmful physical agents and substances which will describe exposure levels that are safe for various periods of employment, including, but not limited to, the exposure levels at which no employee will suffer impaired health or functional capacities or diminished life expectancy as a result of his work experience.

This Department's criteria document has been programmed for completion in this fiscal year in accordance with provisions of the Occupational Safety and Health Act.

The criteria document contains much of the supplemental information required by Section 6(b) and 6(c) of the Act to be in the final standard.

The recommendations for an occupational exposure standard for noise take into consideration available information on health effects and limited data on technical feasibility of achieving various levels of exposure.

The criteria document was reviewed by nine knowledgeable consultants, two professional societies, government agencies with interest and responsibility in occupational safety and health, and input resulting from the *Federal Register* request for information. All reviewers were of the opinion that the recommended noise standard of 85 dBA for 8-hour exposures was appropriate, but that a delay time be incorporated before such a level becomes effective so as to permit industry the time necessary to develop technologically feasible methods and controls to comply with such a level. Furthermore, the reviewers suggested this based upon the consideration of not destroying the progress that has been made in many occupational operations under the currently acceptable 90 dBA level. Due to the lack of sufficient data relating to technological feasibility, no specific time could be recommended for making the 85 dBA level applicable to established installations.

The document recommends control of worker exposure to the occupational limits stated, and most reviewers felt that adherence to the precautionary procedures prescribed will protect essentially all of the worker population from incurring noise-induced hearing loss that could impair their abilities to understand everyday speech.

The substantial changes incorporated into the criteria document as a result of the reviewers' comments involved the delay of the effective date of the 85 dBA 8-hour exposure level, the utilization of ear protectors for workers exposed to effective noise levels exceeding 115 dBA, and environmental monitoring procedures.

Comments by official agencies with interest and responsibilities in occupational health and HEW consultants will be made available to the Ad Hoc Committee to be appointed by the Department of Labor.

The following is the first chapter of the criteria document. It contains the NIOSH recommendations for controlling worker exposure to Noise.

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health

The National Institute for Occupational Safety and Health (NIOSH) recommends that employee exposure to noise in the workplace be controlled by requiring compliance with the standard set forth in the following sections. Control of employee exposure to the occupational limits stated and adherence to the precautionary procedures prescribed will improve the protection of the working population from incurring noise induced hearing loss that could impair their abilities to understand everyday speech. Such control and adherence at the workplace is believed sufficiently effective also to reduce the possibility of other forms of occupational injury and illness related to noise.

This standard is amenable to techniques that are valid, reproducible, and presently available. It will be reviewed and revised as additional information becomes available.

Section 1 — Applicability

The provisions of this standard are applicable to occupational noise exposures at places of employment and are intended to apply for all noise even though additional controls may be necessary for certain specific types of noise, such as some impact and impulsive noise. For the purposes of this standard the noise exposure is determined for an 8-hour workday.

Section 2 — Definitions

As used in this standard, the term:

(a) "Administrative control" means any procedure that limits daily exposure to noise by control of the work schedule.

(b) "Audiogram" means a graph or table obtained from an audiometric examination showing hearing level as a function of frequency.

(c) "Baseline audiogram" means an audiogram obtained from an audiometric examination that is preceded by a period of at least 14 hours of quiet.

(e) "Audiometer setting" means a setting on an audiometer corresponding to a specific combination of hearing level and sound frequency.

(f) "Daily Noise Dose" means that value for D derived from the equation:

$$D = \frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots + \frac{C_n}{T_n}$$

where $C_1, C_2, \ldots, C_n$ are the actual durations of exposure for an employee at the various noise levels; $T_1, T_2, \ldots, T_n$ are the respective duration limits obtained from Figure I-1; and D is the Daily Noise Dose.

(g) "dBA - Slow" means the unit of measurement of sound level indicated by a sound level meter conforming as a minimum requirement to the American National Standard Specification for Sound Level Meters, ANSI S1.4 (1971) Type S2A, when used for A-weighted sound level, slow response.

(h) "Engineering control" means any procedure other than administrative control that reduces the sound level either at the source of the noise or in the hearing zone of the employees.

(i) "Hearing level" means the amount, in decibels, by which the threshold of audibility for an ear differs from a standard audiometric threshold.

(j) "Environmental noise level" means the noise level in dBA-Slow as measured in accord with Section 3(c).

(k) "Effective noise level" means (1) for employees not wearing ear protectors, the environmental noise level; (2) for employees wearing ear protectors, the result of subtracting the dBA reduction, R, for the ear protectors (determined as specified in Appendix A) from the measured environmental noise level. Effective noise level is expressed in units of dBA-Slow.

(l) "Noise exposure" means a combination of effective noise level and exposure duration.

Section 3 — Occupational Environment

(a) The unit of measurement shall be "dBA-Slow."

(b) Daily Occupational Noise Exposure

(i) Occupational noise exposure shall be controlled so that no worker shall be exposed in excess of the limit described as line B in Figure I-1. New installations shall be designed with noise control so that the noise exposure does not exceed the limits described as line A in Figure I-1. For noise exposures consisting of two or more periods of exposure at different levels, the Daily Noise Dose, D, shall not exceed unity. Line A or line B, as applicable, shall be used in computing the Daily Noise Dose.

(ii) It is recommended that the limit described as line A become effective for all places of employment after a time period determined by the Secretary of Labor in consultation with the Secretary of Health, Education, and Welfare. This delay in effective date for all places of employment is believed necessary to permit the Department of Labor to conduct an extensive feasibility study.

LINE A
FORMULA: $T = 16 \div 2^{(L-80)/5}$
RANGE: 80 to 115 dBA-Slow

LINE B
FORMULA: $T = 16 \div 2^{(L-85)/5}$
RANGE: 85 to 115 dBA-Slow

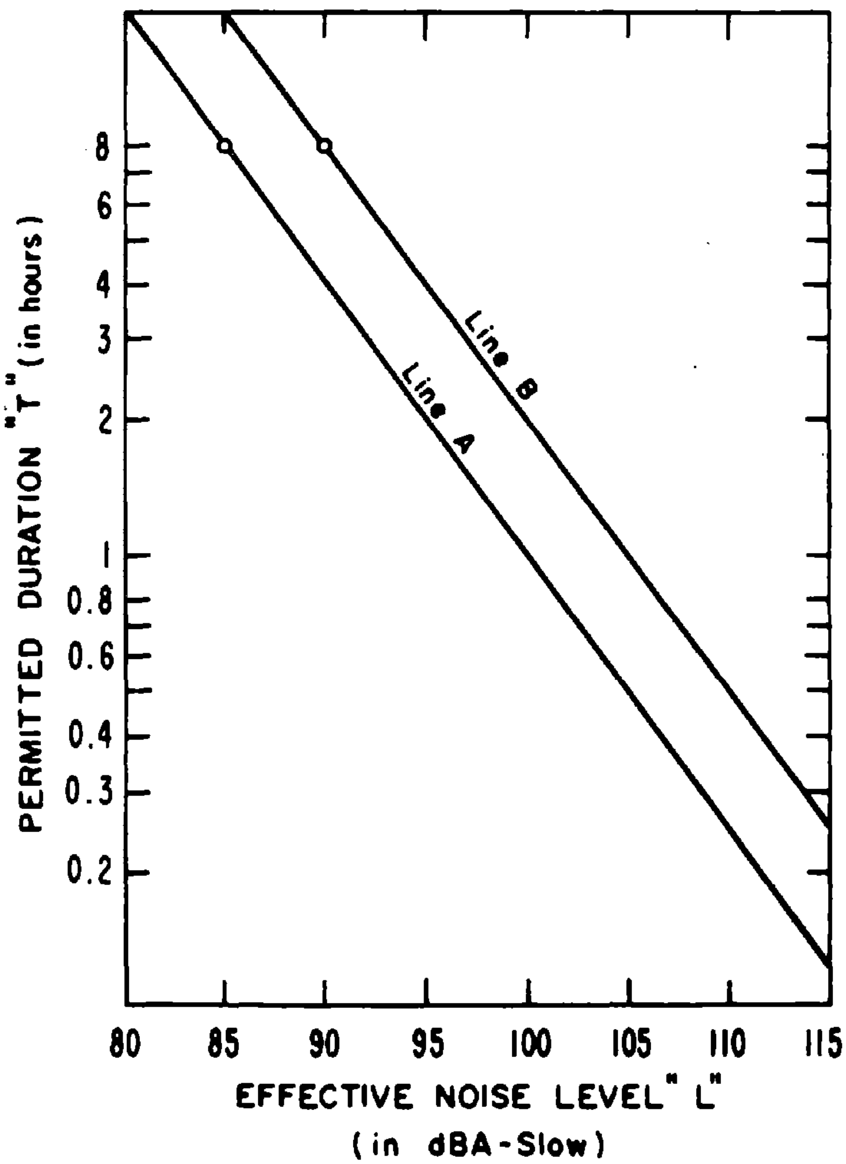

Figure I-1. Permitted duration vs. noise level.*

*The indicated duration limits which exceed 8 hours are to be used only for purposes of computing Daily Noise Dose and are not to be regarded as defining noise exposure limits for work days which exceed 8 hours.

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(iii) At no time shall any worker be exposed to effective noise levels exceeding 115 dBA-Slow.

(c) Measurements

(i) Compliance with the permitted daily noise exposures defined by Section 3(b) shall be determined on the basis of measurements made with a sound level meter conforming as a minimum to the requirement of the American National Standard Specification for Sound Level Meters, S1.4 (1971) Type S2A, and set to use an A-weighted slow response.

(ii) All measurements shall be made with the sound level meter at a position which most closely approximates the noise levels at the head position of the employee during normal operations.

(iii) An acoustical calibrator accurate within plus or minus one decibel shall be used to calibrate the sound level meter on each day that noise measurements are taken.

Section 4 — Medical

(a) Medical surveillance in the form of an audiometric testing program shall be provided by the employer when the Daily Noise Dose, D, equals or exceeds the limits specified in Section 3(b), and for all employees whose occupational noise exposure is controlled by personal protective equipment.

(b) The audiometric testing program required by (a) above shall conform to the following schedule:

(i) A baseline audiogram for each employee who is initially assigned or reassigned to work subject to conditions stated in (a) of this section shall be taken within 30 days of assignment to such employment, in the sixth year of such employment, and once every sixth year thereafter. It is recognized that some delay in implementation of this requirement may be necessary for employers with a small work force.

(ii) A baseline audiogram should be taken for each employee presently assigned to work subject to conditions stated in (a) of this section at the time of effective date of this regulation, in the sixth year, and once every sixth year thereafter.

(iii) In addition, an audiogram, not necessarily baseline, for all exposed employees should be taken every second year.

(c) Each audiogram shall contain (1) employee's name or identifying number, (2) employee's job location, (3) significant aural medical history of the employee, (4) the examiner's name and signature, (5) the date and time of test, (6) serial number of the audiometer, and (7) last exposure to high level noise: number of hours since exposure; type of exposure; and noise level, if known.

(d) Each employee's audiogram shall be examined to determine whether it indicates for either ear any threshold shift (higher threshold) that equals or exceeds 10 dB at 500, 1000, 2000, or 3000 Hz; or 15 dB at 4000 or 6000 Hz, as evidenced by a comparison of that audiogram with the employee's most recent baseline audiogram and with his initial baseline audiogram as corrected to his current age by the method described in Appendix B. If either comparison indicates a shift as described above:

(i) refer the employee for appropriate medical evaluation,

(ii) if the employee needs personal protective equipment or devices, insure that he has the appropriate effective equipment and that he is instructed in the proper use and care of the equipment, and

(iii) if the audiogram was not a baseline audiogram, take a baseline audiogram within 60 days.

(e) Audiometric tests shall be pure tone, air-conduction, hearing threshold examinations, with test frequencies including 500, 1000, 2000, 3000, 4000, and 6000 Hz and shall be taken separately for the right and left ears.

(i) The tests shall be conducted in a room whose ambient noise levels conform to all requirements except that part concerning octave bands whose center frequencies are less than 250 Hz of the American National Standard Criteria for Background Noise in Audiometer Rooms, ANSI S3.1 (1960 R-1971), when measured by equipment conforming to American National Standard Specification for Sound Level Meters, ANSI S1.4 (1971) Type 2 and American National Standard Specification for Octave, Half-Octave, and Third-Octave Band Filter Sets, ANSI S1.11 (1966, R-1971).

(ii) The tests shall be administered using an audiometer which conforms to the requirements for limited range pure tone audiometers prescribed by the American National Standards Specifications for Audiometers, ANSI S3.6 (1969), and which is of the discrete frequency type. If a pulsed tone audiometer is used, the on-time of the tone shall be at least 200 milliseconds. The instrument used in the testing shall be either a manual audiometer, or a self-recording audiometer which is subject to the following additional restrictions:

(1) The chart upon which the audiogram is traced shall have printed lines at positions corresponding to all multiples of 10 dB hearing level within the intensity range spanned by the audiometer. The lines shall be equally spaced and shall be separated by at least 1/4 inch. Additional graduations are optional. The pen which traces the audiogram shall have a fine

point so that the tracing shall not exceed 2 dB in width.

(2) It shall be possible to disable the stylus drive mechanism so that the stylus can be manually set at the 10-dB graduation lines for calibration purposes.

(3) The slewing rate for the audiometer attenuator shall be 6 dB/sec or less except that an initial slewing rate greater than 6 dB/sec is permitted at the beginning of each new test frequency, but only until the second subject response.

(4) The audiometer shall remain at each required test frequency for 30 seconds (± 3 seconds). The audiogram shall be clearly marked at each change of frequency and the actual frequency change of the audiometer shall not deviate from the frequency boundaries marked on the audiogram by more than ± 3 seconds.

(5) If an audiogram fails to pass the following criteria, the subject shall be retested: At each test frequency it must be possible to place a horizontal line segment parallel to the time axis on the audiogram, such that the audiometric tracing crosses the line segment at least six times at that test frequency.

(iv) The audiometer shall be maintained in calibration in accordance with the provisions of Appendix C.

Section 5 — Work Practices

When employees are employed under conditions where noise exposures would exceed the limits prescribed in Section 3(b), administrative or engineering controls shall be utilized to reduce exposures to within those limits.

Section 6 — Warning Notice

(a) A warning sign shall be appropriately located at entrances to and/or the periphery of areas where there exists sustained environmental noise at or in excess of the limit prescribed in Section 3(b).

(b) The notice shall consist of the following:

WARNING

NOISE AREA
MAY CAUSE HEARING LOSS

Use Proper Ear Protection

Section 7 — Personal Protective Equipment

(a) If noise exposures to which employees could be exposed exceed the limits specified, personal protective equipment (i.e., ear protectors) shall be provided by the employer to be used in conjunction with an audiometric testing program, as specified in Section 4, subject to the following requirements:

(i) The use of personal protective equipment to prevent occupational noise exposure of the employee in excess of the prescribed limits is authorized only until engineering and administrative controls and procedures can be implemented to maintain the occupational noise exposures within prescribed limits.

(ii) Any ear protector used by an employee shall reduce the effective noise level to which he is exposed so that his noise exposure is within the limits prescribed in Section 3(b).

(iii) Insert - type ear protectors shall be fitted by a person trained in this procedure.

(iv) Inspection procedures to assure proper issuance, maintenance, and use of personal protective equipment shall be established by the employer.

(b) The employer shall provide training in the proper care and use of all personal protective equipment.

Section 8 — Apprisal of Employees of Hazards from Noise

Each worker exposed to noise shall be apprised of all hazards, relevant symptoms, and proper conditions and precautions for working in noisy areas. The information shall be kept on file and readily accessible to the worker at all places of employment where the noise levels equal or exceed the limits prescribed in Section 3 (b).

Section 9 — Monitoring & Recordkeeping Requirements

(a) Employers will be required to maintain records of:

(i) environmental exposure monitoring for a period of 10 years.

(ii) all audiograms for a period of 20 years.

(iii) all audiometric calibration data for a period of 20 years.

(b) When exposure times of less than 8 hours/day are required in a specific work area or ear protection is used to meet the exposure limits, records of the method of control shall be maintained.

Appendix A — Determination of dBA Reduction R for Ear Protectors

1. The pure tone attenuation vs. frequency characteristics of the ear protector (normally supplied by the manufacturer) shall have been determined in accordance with the American National Standard for Measurement of the Real-Ear Attenuation of Ear Protectors at Threshold, ANSI Z24.22 (1957). Let Q_1, Q_2, ..., Q_7 be defined (in dB) as follows:

Q_1 = attenuation at 125 Hz, plus 16.2 dB
Q_2 = attenuation at 250 Hz, plus 8.7 dB
Q_3 = attenuation at 500 Hz, plus 3.3 dB
Q_4 = attenuation at 1000 Hz
Q_5 = attenuation at 2000 Hz, minus 1.2 dB
Q_6 = average of attenuation at 3000 and 4000 Hz, minus 1.0 dB
Q_7 = average of attenuations at 6000 and 8000 Hz, plus 1.1 dB

2. The following procedure shall be used to determine the dBA reduction R of the ear protector when used for an occupational noise whose octave-band sound pressure levels have been measured.

Let L_1, L_2, L_3, L_4, L_5, L_6 and L_7 denote the octave band levels in dB at 125, 250, 500, 1000, 2000, 4000, and 8000 Hz respectively; and let L_A denote the dBA-Slow level of the noise. Then the dBA reduction as connected is given by $R = L_A - 10 \log S - 10.0$

where

S = antilog (0.1X [$L_1 - Q_1$]) + antilog (0.1 X [$L_2 - Q_2$])
+ antilog (0.1 X [$L_3 - Q_3$]) + antilog (0.1 X [$L_4 - Q_4$])
+ antilog (0.1 X [$L_5 - Q_5$]) + antilog (0.1 X [$L_6 - Q_6$])
+ antilog (0.1 X [$L_7 - Q_7$])

The "-10.0" correction term is to account for possible noise spectrum irregularities and noise leakage which might be caused by long hair, safety glasses, head movement, or various other factors.

3. If the octave band levels of the noise are not known, then the dBA reduction R may be computed simply as

$R = -10 \log S - 3.0$

where

S = antilog (-0.1 X Q_1) + antilog (-0.1 X Q_2)
+ antilog (-0.1 X Q_3) + antilog (0.1 X Q_4)
+ antilog (-0.1 X Q_5) + antilog (-0.1 X Q_6)
+ antilog (-0.1 X Q_7)

This calculation is approximate, and is based upon the assumption that the octave band levels are equal. For most types of noise it will give results close to those obtained by the more accurate method of (2) above.

Example:

Typical Pure-tone Attenuation Characteristics of an Ear Protector

125	250	500	1000	2000	3000	4000	6000	8000	Hz
24	21	23	29	30	35	31	29	27	dB

Thus Q_1 = 40.2; Q_2 = 29.7; Q_3 = 26.3; Q_4 = 29.0; Q_5 = 28.8; Q_6 = 31.0; Q_7 = 29.1

If the octave band noise levels are not known, then

$R = -10 \log S - 3.0$

where

S = antilog (-4.02) + antilog (-2.97) + antilog (-2.63)
+ antilog (-2.90) + antilog (-2.88) + antilog (-3.10)
+ antilog (-2.91)

or S = 0.00811

So R = -10 log. 0.0081 - 3.0 = 20.9 - 3.0 ≅ 18 dBA

Now suppose the ear protector is to be used in an area with an environmental noise level of 95 dBA, for which the octave band noise levels are as follows:

125	250	500	1000	2000	4000	8000	Hz
99	94	94	90	84	82	75	Octave Band Level

In this case the dBA reduction is

$$R = L_A = 10 \log S - 10.0$$

Where S = antilog (9.9 - 4.02) + antilog (9.4 - 2.97) + antilog (9.4 - 2.63)
+ antilog (9.0 - 2.90) + antilog (8.4 - 2.88) + antilog (8.2 - 3.10)
+ antilog (7.5 - 2.91). So S = 11,090,000
Thus R = 95.0 - 10 x 7.05 - 10.0 ≅ 85.0 - 70.5
So R = 14.5 dBA

Appendix B — Method for Correcting Initial Baseline Audiograms for Age

Age corrections to initial baseline audiograms shall be made in the following manner:
For each audiometric test frequency:

1. Determine from Table B-1 or B-2 the age correction values for the employee
   (a) for the age at which the most recent audiogram was taken and
   (b) for the age at which the initial baseline audiogram was taken.
2. Subtract the values found in (a) from the values found in (b).
3. Add the difference found in 2 to the employee's initial baseline audiogram to obtain the initial baseline audiogram corrected for age.

EXAMPLE: Employee is 56 years old and male. His initial baseline audiogram was taken at age 26 and his hearing levels at that age were as follows:

Hz	500	1000	2000	3000	4000	6000
Left ear	5	0	10	5	10	10
Right ear	10	0	5	0	5	15

Enter Table B-1 at age 56 and at age 26 and subtract.

Hz	500	1000	2000	3000	4000	6000
Age 56	16	10	11	20	28	34
Age 26	11	5	4	5	7	10
Difference	5	5	7	15	21	24

Add the differences to his initial baseline audiogram to obtain his corrected initial baseline audiogram as follows:

Hz	500	1000	2000	3000	4000	6000
Left ear	10	5	18	20	31	34
Right ear	15	5	13	15	26	39

TABLE B—1

Age Corrections Values to be Used for Age Correction of Initial Baseline Audiograms for Males

Age	Audiometric Test Frequencies (Hz)					
Years	500	1000	2000	3000	4000	6000
20 or younger	10	5	3	4	5	8
21	10	5	3	4	5	8
22	10	5	3	4	5	8
23	10	5	3	4	6	9
24	10	5	3	5	6	9
25	11	5	3	5	7	10
26	11	5	4	5	7	10
27	11	5	4	6	7	11
28	11	6	4	6	8	11

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TABLE B—1 (Continued)

Age Corrections Values to be Used for Age Correction of Initial Baseline Audiograms for Males

Age	Audiometric Test Frequencies (Hz)					
Years	500	1000	2000	3000	4000	6000
29	11	6	4	6	8	12
30	11	6	4	6	9	12
31	12	6	4	7	9	13
32	12	6	5	7	10	14
33	12	6	5	7	10	14
34	12	6	5	8	11	15
35	12	7	5	8	11	15
36	12	7	5	9	12	16
37	13	7	6	9	12	17
38	13	7	6	9	13	17
39	13	7	6	10	14	18
40	13	7	6	10	14	19
41	13	7	6	11	15	20
42	14	8	7	11	16	20
43	14	8	7	12	16	21
44	14	8	7	12	17	22
45	14	8	7	13	18	23
46	14	8	8	13	19	24
47	14	8	8	14	19	24
48	15	9	8	14	20	25
49	15	9	9	15	21	26
50	15	9	9	16	22	27
51	15	9	9	16	23	28
52	15	9	10	17	24	29
53	16	9	10	18	25	30
54	16	10	10	18	26	31
55	16	10	11	19	27	32
56	16	10	11	20	28	34
57	16	10	11	21	29	35
58	17	10	12	22	31	36
59	17	11	12	22	32	37
60 or older	17	11	13	23	33	38

TABLE B—2

Age Corrections Values to be Used for Age Correction of Initial Baseline Audiograms for Females

Age	Audiometric Test Frequencies (Hz)					
Years	500	1000	2000	3000	4000	6000
20 or younger	15	7	4	3	3	6
21	16	7	4	4	3	6
22	16	7	4	4	4	6
23	16	7	5	4	4	7
24	16	7	5	4	4	7
25	16	8	5	4	4	7
26	16	8	5	5	4	8

TABLE B—2 (Continued)

Age Corrections Values to be Used for Age Correction of Initial Baseline Audiograms for Females

Age Years	Audiometric Test Frequencies (Hz) 500	1000	2000	3000	4000	6000
27	17	8	5	5	5	8
28	17	8	5	5	5	8
29	17	8	5	5	5	9
30	17	8	6	5	5	9
31	17	8	6	6	5	9
32	17	9	6	6	6	10
33	18	9	6	6	6	10
34	18	9	6	6	6	10
35	18	9	6	7	7	11
36	18	9	7	7	7	11
37	18	9	7	7	7	12
38	18	10	7	7	7	12
39	19	10	7	8	8	12
40	19	10	7	8	8	13
41	19	10	8	8	8	13
42	19	10	8	9	9	13
43	19	11	8	9	9	14
44	20	11	8	9	9	14
45	20	11	8	10	10	15
46	20	11	9	10	10	15
47	20	11	9	10	11	16
48	20	12	9	11	11	16
49	21	12	9	11	11	16
50	21	12	10	11	12	17
51	21	12	10	12	12	17
52	21	12	10	12	13	18
53	21	13	10	13	13	18
54	21	13	11	13	14	19
55	22	13	11	14	14	19
56	22	13	11	14	15	20
57	22	13	11	15	15	20
58	22	14	12	15	16	21
59	22	14	12	16	16	21
60 or older	23	14	12	16	17	22

Appendix C — Procedures for Calibration of Audiometers

The accuracy of an audiometer shall be determined by (1) a biological calibration, (2) a periodic calibration, and (3) an exhaustive calibration.

A. A biological calibration shall be made at least once each month and shall consist of (1) testing a person having a known stable audiometric curve that does not exceed 25 dB hearing level at any frequency and comparing the test results with the known curve and (2) registering the subject's response to distortions and unwanted sounds from the audiometer. If the results of a biological calibration indicate hearing-level differences greater than ± 5 dB at any frequency, if the signal is distorted, or if there are attenuator or tone switch transients, then the audiometer shall be subjected to a periodic calibration within thirty days.

B. A periodic calibration shall be performed at least annually or as indicated by results of a biological check and shall include the following:

(1) Set audiometer to 70 dB hearing threshold level and measure sound pressure levels of test tones using an NBS-9A-type coupler, for both earphones and at all test frequencies.

(2) At 1000 Hz, for both earphones measure the earphone decibel levels of the audiometer for 100

dB settings in the range 70 to 10 dB hearing threshold level. This measurement may be made acoustically with a 9A coupler, or electrically at the earphone terminals.

(3) Measure the test tone frequencies with the audiometer set at 70 dB hearing threshold level, for one earphone only.

(4) In making the measurements in (1) - (3) above the accuracy of the calibrating equipment shall be sufficient to prove that the audiometer is within the tolerances permitted by ANSI S3.6-1969.

(5) A careful listening test, more extensive than that required in the biological calibration, shall be made in order to ensure that the audiometer displays no evidence of distortion, unwanted sound, or other technical problems.

(6) General function of the audiometer shall be checked, particularly in the case of a self-recording audiometer.

(7) All observed deviations from required performance shall be corrected.

C. An exhaustive calibration shall be performed at least every five years. This shall include testing at all settings for both earphones. The test results must prove unequivocally that the audiometer meets for the following parameters the specific requirements stated in the applicable sections of ANSI-S.3-1969 as noted in parenthesis.

(1) Accuracy of decibel level settings of test tones (Sections 4.1.4.1 and 4.1.4.3).

(2) Accuracy of test tone frequencies (Section 4.1.2).

(3) Harmonic distortion of test tones (Section 4.1.3).

(4) Tone-envelope characteristics, i.e., rise and decay times, overshoot, "off" level (Section 4.5).

(5) Sound from second earphone (Section 4.4.2).

(6) Sound from test earphone (Section 4.4.1).

(7) Other unwanted sound (Section 4.4.3).

Testimony of

Dr. John F. Finklea
Director
National Institute for Occupational Safety and Health

Presented at the

Occupational Safety and Health Administration
U.S. Department of Labor
Public Hearings
on
Proposed Standard for Occupational Noise

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control

June 23, 1975

I am Dr. John Finklea, Director of the National Institute for Occupational Safety and Health (or NIOSH). I appreciate the invitation to summarize NIOSH's position regarding an occupational noise standard. With me are Drs. Terry Henderson and Alexander Cohen, two of NIOSH's noise researchers. We will be happy to answer any questions or provide additional clarifying comments bearing on the subject of this hearing.

In August, 1972, NIOSH submitted to the Department of Labor a Criteria Document entitled, "Occupational Exposure to Noise," containing recommendations for a new workplace noise standard accompanied by relevant background data.[1] This NIOSH action was in accordance with Sections 20(a)(3) of the Occupational Safety and Health Act of 1970[2] which directed our Institute to develop criteria and to define safe exposure limits for toxic materials and harmful physical agents in places of employment. The NIOSH proposals called for extensive changes in the then existing occupational noise regulation. The Department of Labor's plans for revising this standard, published in the Federal Register, October 24, 1974,[3] incorporate many of the features found in the original NIOSH recommendations.

The stated purpose of the Department of Labor's proposed revision is to minimize the risk of hearing impairment from exposures to hazardous levels of occupational noise. To attain this end, it proposes retention of 90 dBA as a noise limit for an 8-hour workday exposure, with a 5 dB increment in permissible level for successive halving of exposure time. NIOSH concurred with this position in its criteria document. However, recognizing the need for more complete noise protection, NIOSH also recommended eventual lowering of this exposure limit to 85 dBA. In this regard, it was recommended that the new noise standard should require new work establishments to comply with the 85 dBA limits, and ultimately require all establishments to meet this stricter limit. Our concern about permanently retaining the 90 dBA limit is based on the following points:

1. Analysis of data from our own studies[1,4] and other sources[5,6] indicate to us that as many as 10 to 15 more persons per hundred may incur a beginning hearing handicap as a result of a working lifetime of exposure to 90 dBA verses 85 dBA. The affected population may be quite large.

2. A 90 dBA exposure limit may not provide sufficient protection to the higher frequencies in one's audiogram which are more vulnerable to noise damage. On this point, the protection goals of most recommended noise standards, including the one proposed by the Department of Labor, have been to restrict hearing loss for frequencies 500, 1000 and 2000 Hertz owing to their importance to hearing for speech. Available data show that 3000 Hertz may also be important to speech reception, especially under less-than-optimum listening conditions.[7,8,9] Thus, NIOSH reasons that a more stringent limit, by curtailing losses at 3000 Hertz, would better preserve hearing for everyday speech reception.

3. We are now concerned that the proposed standard may allow excessive exposures for periods of less than eight hours. We now believe that a 5 dBA step function is appropriate for an 85 dBA standard but may not provide adequate protection for a 90 dBA standard.

4. The adoption of a less stringent noise exposure limit for hearing conservation could permit other forms of noise-induced effects of possible consequence to safety and health. The proposed Department of Labor limit, for example, would allow up to two hours per day of noise exposures at 100 dBA. Such noise levels make voice communication difficult if not impossible and can readily mask warning shouts and audio alarms.[10] Whereas the recommended limits are built on the premise that frequent interruptions make higher levels of noise more tolerable to the ear, this condition is more likely to disrupt task performance, as has been demonstrated by laboratory research.[11] To the extent that these impediments to communication and performance might increase the risk of accidents at work, a hearing conservation criterion permitting high levels of noise for even short durations could prove underprotective.

   Perhaps those of you who travel extensively but do not work in a noisy factory can better understand the difference between exposures of 85 dBA and 90 dBA by the following example. Sitting in the seat immediately adjacent to a body mounted jet engine exposes you to 90 dBA during flight while a seat at the juncture of the smoking and nonsmoking sections allows an exposure of 85 dBA. After several hours exposure to 90 dBA, I can't hear very well and I become extremely irritable.

Since the publication of the NIOSH Criteria Document in 1972, our agency has increased its research efforts in the area of extra-auditory noise effects, and they deserve some elaboration here.

Currently in progress is a laboratory study[12] which is examining whether the senses of vision, balance, touch and thermal sensation can be affected by short-term high-level continuous noise and impact sounds, that do not exceed the exposure limits proposed by the Department of Labor. In actuality, the laboratory noise conditions mostly consist of 15 minute exposures to 110 dBA continuous noise or to 135 dB peak-level impacts occurring every two seconds. Evidence to date shows only the visual sense to be noise-sensitive, with slight but statistically significant losses occurring, as evidenced by impaired detection of lights in the periphery, elevated thresholds for flicker fusion, and slow adaptation to darkness. Research is now underway to determine the extent to which some of these effects may be accentuated or otherwise modified by variations in the noise conditions. Later tests will explore whether job tasks dependent on these noise-sensitive functions can be adversely affected by noise conditions, regarded as safe for hearing. If so, added considerations for specifying noise protective limits would seem to be advisable.

These comments have been directed toward noise effects of an acute nature. Recurrent, prolonged exposure to noise, typical for may heavy industries, has <u>also</u> been alleged to contribute to various chronic stress-related disorders. Admittedly, the inability to rule out other factors which could also lead to these disturbances raises some questions about this claim. That a need exists for more definitive studies in this area is clearly recognized. NIOSH has just completed a contract study in which the medical, attendance, and accident record data of over 400 workers in a boiler-making plant were collated and compared for 2-year periods prior to and following the establishment of a hearing conservation program involving use of personal car protection.[13] Comparisons by worker age, length of service, workshift, job type and ear protector use yielded significant differences showing fewer medical problems, absences, and job accidents after the advent of the ear protection program. Only symptomatic complaint data showed no significant change. Comparable records from a group of workers from quieter areas of the same plant showed no substantial changes over the same two time periods, suggesting that the observed effects could not be accounted for by any plant-wide influences. The relationships between the use of ear protectors and a reduced frequency of extra-auditory problems did not follow a consistent, clear pattern. Difficulties in rating the use of ear protectors may have been responsible for this result.

While the findings from this study cannot serve to specify permissible noise limits, they do suggest a connection between high level noise exposure and increased incidence of medical problems, absences, and job accidents. Moreover, a hearing conservation program can be beneficial in reducing these types of problems as well as hearing loss risk. This added dividend should be noted in considering cost/benefit issues related to industrial noise control.

One last observation must be made regarding noise problems other than hearing loss. Several weeks ago, a worker fatality was reported in a power plant in the Cincinnati area. An investigation revealed that the accident victim and his fellow workers, irritated by the screeching sounds from a pulley drive in a conveyor system, had resorted to repeated "soaping" of the pulley unit to quiet the sound. Gaining access to the pulley for this purpose involved certain risks that were contrary to company work policy. Despite this, a worker in the course of soaping the pulley evidently became caught, was pulled into the moving conveyor and was killed.

It is doubtful that even an 85 dBA noise limit would have prevented this accidental death. Yet the case deserves mention if only to show that non-auditory problems of noise cannot be ignored. Indeed, it should motivate more conservative approaches in specifying noise limits meeting both health and safety needs.

Before concluding I would like to draw attention to a few other aspects of the proposed noise standard:

We concur with the Department of Labor's proposal that personal protective equipment in the form of ear plugs or muffs should be regarded only as a temporary measure while suitable engineering controls and administrative measures are being developed. We believe that the noise should be abated by application of engineering technology. Personal protective devices should be used as an interim measure until effective engineering controls can be established.

The Department of Labor's proposed provisions for audiometric monitoring, although not entirely identical to NIOSH's original recommendations, constitute a reasonable set of minimum requirements for industrial hearing conservation practice. We are confident that a variety of specialized features will be incorporated into industrial programs by the professionals in charge. We believe adequate equipment and trained manpower can be made available to meet these requirements. We would, however, like to reemphasize the need for specific wording in the standard requiring that any employee showing signs of progressive hearing loss should be referred for appropriate medical evaluation.

The original NIOSH document did not contain recommendations concerning impact noise because it was felt that further study was required before suitable criteria could be developed and verified. Recent results of NIOSH-funded research have confirmed that this serious problem is not, as yet, well understood.[14] However, NIOSH does not object to the impact noise limit proposed by the Department of Labor, since it would clearly provide more protection than the present standard.

In conclusion, I would like to urge that every effort be made to promulgate the new regulations without further delay. The issues have been exhaustively scrutinized by those concerned, and it is time for a decision.

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Joint Testimony of

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Presented before the

Government Regulation Subcommittee
Senate Small Business Committee

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control

July 23, 1975

I am Dr. John Finklea, Director of the National Institute for Occupational Safety and Health (or NIOSH). With me are Drs. Alexander Cohen and Terry Henderson, two of NIOSH's noise researchers. We appreciate the invitation to appear before the subcommittee to discuss the effects of industrial noise pollution on human health and the actions taken by our agency in the interest of protecting the nation's workers against the hazards of noise.

By way of professional experience, Dr. Cohen has been involved in noise effects research for many years and has published extensively on the subject. In recent years he has concentrated upon the extra-auditory effects of noise, with particular reference to work safety, stress, and the effects of noise on sensory functions other than hearing. Since 1972, Dr. Henderson has directed NIOSH's noise research involved with hearing conservation and related acoustical problems. He is the public health service representative to the Acoustical Standards Management Board of the American National Standards Institute. Both Drs. Cohen and Henderson have participated in noise criteria activities of the World Health Organization, The Committee on Hearing and Bioacoustics of the National Academy of Sciences, and the Environmental Protection Agency.

The Occupational Safety and Health Act of 1970 established our institute with one of its primary functions being to develop scientific criteria and to define safe exposure limits for toxic materials and harmful physical agents in place of employment[1]. In accordance with this responsibility, NIOSH prepared a criteria document entitled, "Criteria for a Recommended Standard . . . Occupational Exposure to Noise"[2]. The submittal of this criteria document to the Department of Labor in 1972 was a key step in a regulatory process which is still in motion, as evidenced by the current public hearings being held by the Occupational Safety and Health Administration on its new proposed workplace noise standard.

Workplace noise exposures, especially those occurring in mechanized industries, are likely to be the most intense and prolonged of any experienced in daily living. Because of their increased severity, occupational noise exposures can be considered as posing a greater threat to one's health and well-being than general environmental noise. Evidence exists connecting occupational noise exposures with the following adverse effects:

- loss of hearing[2,3,4,5,6]

- interference with the reception of other desired sounds, referred to as "masking"[2,7]

- physiological and psychological disturbances[2,8,9,10,11]

- disturbance of work performance and behavior[2,9]

There is general agreement that loss of hearing is the most significant health hazard caused by over-exposure to noise. For this reason, the thrust of industrial noise research concerned with health effects has been on this problem. Field surveys of noise and hearing in different occupations have been conducted by our Institute and other groups to define the extent of the hazard[2,6]. Laboratory investigations have attempted to evaluate the potency of different types of noise conditions for causing hearing loss and other factors that could influence ear tolerance to noise[16,17].

Recognizing this health hazard, standards for industrial noise exposure have been largely aimed at safeguarding hearing. The stated intent of the Department of Labor's proposed revision of the existing occupational noise regulation, for example, is to "minimize the risk of hearing impairment from exposures to hazardous levels of occupational noise"[12]. Toward this end, the Department of Labor recommended retention of 90 decibels* as a noise limit for an 8-hour workday. Exposure with a formula permitting higher levels for shorter durations. NIOSH gave its position of this proposed noise standard at the public hearings which are still in progress. In doing so, it reaffirmed the recommendations that were included in the NIOSH criteria document. While these recommendations indicated concurrence with the limit proposed by the Department of Labor, NIOSH also recommended eventual lowering of this limit to 85 decibels. More specifically, it proposed that new work establishments comply with the 85 decibel limit and ultimately all establishments meet this stricter requirement.

Perhaps those of you who travel extensively can better understand the difference between exposures of 85 and 90 decibels by the following example. Sitting in the seat immediately adjacent to a body mounted jet engine exposes you to 90 decibels during flight while a seat at the juncture of the smoking and non-smoking sections allows an exposure of 85 decibels. After several hours exposure to 90 decibels, I can't hear very well and I become extremely irritable. This may or may not be the case with others, but long-term exposures surely would affect most people.

In support of its position NIOSH reasoned, based upon data from its own studies[2,3] and other sources[5,6], that the stricter 85 decibel limit would significantly reduce the risk of a beginning hearing handicap for persons subjected to a working lifetime of daily noise exposures. Moreover, it would curtail losses in hearing for higher pitched sounds that can be important in understanding speech under everyday listening conditions[13,14].

The adoption of a more stringent noise exposure limit for hearing conservation could also reduce the possible occurrence of other types of noise induced effects of possible consequence to health and safety. For example, going from a 90 to an 85 decibel limit would have the additional benefit of cutting in half the permissible exposure times to those higher levels of noise which are restricted to durations of less than 8 hours. Though the ear can safety tolerate brief exposures to high level noise, such noise intensities can make voice communication difficult to the point of masking warning shouts and interfering with the reception of audio alarms[7]. Reducing exposure times to high level noise could also lessen the possibility of impairments to work performance. Outcomes here, however, can be affected by factors other than sound levels, with the nature of the task and the attitude of the worker being particularly important ones. Available laboratory research indicates that

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*The term "decibel" in this statement refers to sound level (dBA) as measured by a standard sound level meter using the "A" weighting network.

performance error in noise is most likely to occur when there is a combination of conditions consisting of high level interrupted sounds, a fast-paced, difficult task and tense or anxious individuals[9].

A change in behavior as a response to noise is most clearly seen in the startle response which can be provoked by unexpected, loud explosive-like sounds. These reactions may have little significance by themselves but in certain industrial or other situations where there is some accident risk, sudden noise occurrences could startle a person into injuring himself or others. The Department of Labor's proposed noise standard does contain limits for impact or impulse noises which could have a moderating effect on the problem of startle response. This type of response will also diminish with repeated exposures, although some elements of a startle reaction, notably eyeblink, seem to resist this trend.

Since the publication of the NIOSH criteria document in 1972, our agency has continued its noise research programs with increased emphasis in those areas exhibiting significant gaps in our knowledge. Projects currently underway include hearing loss studies of noise exposures of short duration and intermittent noise, reflecting our concerns with the accuracy of existing formulas for trading-off noise level against duration of exposure. Impairment of hearing due to impact or impulsive noises was not addressed in our criteria document and ongoing NIOSH-supported research has indicated that this subject may require much detailed study.

Although hearing loss studies comprise the major portion of our noise research programs, the study of extra-auditory effects has also been accentuated in recent years. In response to the specific suggestion of the subcommittee staff we would like to give some details of our research efforts in this field. Currently in progress, for example, is a laboratory study which is examining whether the senses of vision, balance, touch and thermal sensation can be affected by short term, high level continuous noise and impact sounds that do not exceed the exposure limits proposed by the Department of Labor.

Research is now underway to determine the extent to which some of these effects may be accentuated or otherwise modified by variations in the noise conditions. Later tests will explore whether a job task dependent on these particular functions can be adversely affected by noise conditions regarded as safe for hearing. If so, added considerations for specifying noise protective limits would be advisable.

The extra-auditory effects described so far have represented acute types of reactions in that they are observed during the course of a given noise exposure or immediately afterwards. Recurrent, prolonged exposures to noise, typically found in many heavy industries, have also been alleged to contribute to various chronic, stress related disorders[6,8,10]. Loud noise can trigger changes in cardiovascular, endocrine, neurologic and other physiologic functions which taken together represent a generalized stress reaction of the body. It should be noted that intense light, forced exercise, pain and trauma can elicit similar altered functions. Associated with these bodily changes may be a variety of subjective responses also conveying apparent distress such as fear, alarm, anxiousness, excitability, and irritation. While stress itself may be a factor in the etiology of disease, the issue of whether excessive sound exposures can directly or indirectly lead to health disorders remains controversial. In particular, the inability of past research studies to rule out other factors which could lead to ailments reputed to be due to high level noise raises questions about any such claims. That there is a need for more definitive research study in this area has been clearly recognized. NIOSH has just completed a contract study in which the medical, attendance and accident record data of 400 workers in a boiler making plant were collated and compared for a two-year period prior to and following establishment of a hearing conservation program involving the use of personal ear protection[15]. Comparisons by worker age, length of service, job type and ear protector use yielded significant differences showing fewer medical problems, absences and job accidents after the advent of the ear protection program. Comparable records from a group of workers from quieter areas of the same plant showed no substantial changes over the same two time periods suggesting that the observed effects could not be accounted for by any plant-wide influences. The relationships between the use of ear protectors and a reduced frequency of extra-auditory problems did not follow a consistent, clear pattern but difficulties in rating the use of ear protectors may have been responsible for this result. The findings from this study suggest an association between high level noise exposure and increased incidence of medical problems, absences and job accidents. Moreover, they also suggest that a hearing conservation program can be beneficial in reducing these types of problems as well as hearing loss risk. This added dividend should be noted in considering cost/benefit issues related to industrial noise control.

One last observation must be made regarding noise problems other than hearing loss. Several weeks ago, a worker fatality was reported in a power plant in the Cincinnati area. An investigation revealed that the accident victim and his fellow workers, irritated by the squealing sounds from a pulley drive in a conveyor system, had resorted to repeated "soaping" of the pulley unit to quiet the sound. Gaining access to the pulley for this purpose involved certain risks that were contrary to company work policy. Despite this, a worker in the course of soaping the pulley evidently became caught, was pulled into the moving conveyor and was killed.

It is doubtful that any of the noise limits currently under consideration would have prevented this accidental death. Yet the case deserves mention if only to show that non-auditory problems of noise cannot be ignored. Indeed, it should motivate more conservation approaches in specifying noise standards meeting both health and safety needs.

Before concluding, some mention should be made of our Institute's efforts to promote and improve the technology for combating excessive workplace noise. We have prepared listings of the performance data for commercially available ear plugs and ear muffs and have published procedures for rating the effectiveness of these devices. At present, a major research project is under way to measure the performance of ear plugs under actual working conditions. Also in progress are efforts to refine noise survey methods and techniques for testing the hearing of workers in large numbers.

NIOSH will publish soon two noise control handbooks which should be of value to industries not large enough to have a staff of noise control engineers. The first of these is an exhaustive catalog of the properties of materials available for noise reduction purposes as well as the addresses of suppliers. The second is a basic noise control manual that presents case histories of engineering solutions to noise problems. It even includes a chapter on how to choose and make effective use of a private noise control consultant.

NIOSH also performs certification tests on instruments used in hazard surveys of workplaces and on personal protective equipment. Its proposed procedures for certifying sound level meters have already been published in the Federal Register. Plans for certifying other noise instruments and personal ear protectors are at an advanced stage.

Short courses on occupational safety and health subjects are offered by NIOSH including one dealing with industrial noise. On a limited basis, the Institute also supports demonstration projects for hazard control. One such project involves a study of techniques for quieting punch press machines.

Employers and other persons desiring assistance or information relating to occupational noise problems may contact any one of several NIOSH Regional Offices located throughout the country. These offices can provide information on available consultative services in occupational safety and health including those with suitable qualifications in the areas of noise control, hearing testing, and medical support for hearing conservation programs. As circumstances permit, the NIOSH Regional Office working with our technical services group could offer to conduct a noise survey of the work location where a noise problem is suspected and give control recommendations as needed. This service would be without cost.

We are also providing booklets, pamphlets and other informational aids to both employers and employees. Health and safety guides and manuals of good industrial hygiene practices have already been prepared for a variety of small business operations including auto repair and body shops, gasoline service stations, laundries, print shops, specialty metal shops and others. The majority of these publications contain discussions of the problems of occupational noise and the importance of taking steps to combat it.

As you can see, NIOSH's work on noise problems encompasses research, technical assistance, and information dissemination activities. Moreover, particular efforts are being made to channel the benefits of these activities to the small business establishment.

We will be glad to provide you with any additional information you may desire.

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Statement of

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Presented before the

Subcommittee on Compensation, Health and Safety
House Committee on Education and Labor

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control

October 4, 1977

Mr. Chairman and Members of the Subcommittee:

I am Edward J. Baier, Deputy Director of the National Institute for Occupational Safety and Health (NIOSH). Before coming to NIOSH in 1972, I was Director of the Bureau of Mines and Occupational Health and Safety for the Pennsylvania Department of Environmental Resources. Accompanying me today are Dr. Alexander Cohen and Mr. B. Thomas Scheib, two of NIOSH's noise researchers. Dr. Cohen is Chief of the Behavioral and Motivational Factors Branch in the Division of Biomedical and Behavioral Science. Mr. Scheib is Chief of the Coal Mine Standards Activity in the Division of Criteria Documentation and Standards Development. Both Dr. Cohen and Mr. Scheib participated in the development of the NIOSH criteria document on noise.

We welcome the opportunity to appear before you today to discuss NIOSH research on occupationally-induced hearing loss. In particular you have asked us to discuss the formula by which the Department of Labor determines hearing loss for purposes of compensating Federal employees and other related matters.

NIOSH Criteria Document on Occupational Exposure to Noise

NIOSH and its predecessor occupational health agencies have conducted research for more than 20 years on the problem of hearing loss in workers caused by workplace noise exposure[1-9]. Our primary concern during this time has been devoted to prevention, though, and not with the compensation aspects. In August 1972, NIOSH transmitted a criteria document to the Department of Labor containing recommendations for a new workplace standard for noise control[10]. This was one of the first criteria documents developed, because NIOSH recognized that the prevalence of occupational hearing loss was a high priority concern requiring control. Sizable populations of workers are subject to hearing loss risk in such major industries as iron and steel-making, mining, metal fabrication, textiles, lumbering, and printing and publishing in the private sector of U.S. industry. In Federal establishments, noise hazards to hearing are found in printing and engraving shops, ordinance test areas and arsenals, naval shipyards and many other military service occupations, and transportation together with their associated support facilities. NIOSH estimated in the criteria document that more than 2,500,000 industrial workers are exposed to noise levels potentially hazardous to their hearing in major U.S. industries. This does not include the more than 4.5 million transportation workers, 3.5 million construction workers, 626,000 miners and 4.7 million agricultural workers, nor does it include workers employed by government.

In general, workplace noise exposures, especially those occurring in mechanized industries, are likely to pose a greater threat to an individual's health and well-being than general environmental noise exposures. Loss of hearing is considered to be the most significant health hazard caused by over-exposure to noise and is the focus of our testimony today. Noise can also interfere with the reception of speech, warning signals and other desired sounds, contribute to physiological and psychological disturbances and hinder work performance.

The intent of the NIOSH recommendations for noise control was and is to prevent, or at least minimize, noise-induced disease and injury. The criteria document stressed the need for engineering controls to reduce the intensity of noise in the workplace and administrative controls to limit the amount of exposure each employee receives. The use of ear protectors was sanctioned only as a temporary measure until engineering and administrative controls could be implemented. NIOSH recommended that audiometric tests be given when an employee is initially assigned to a noisy environment and periodically thereafter.

Although the NIOSH criteria document does not specifically deal with the issue of compensation for occupational hearing loss, prevention of hearing loss and hearing loss compensation do become interrelated in the course of developing recommendations for noise control. For example, if the primary socioeconomic value of hearing is presumed to be speech communication, then only that hearing loss which handicaps such communication is considered in establishing compensation awards.

NIOSH set as its goal the preservation of hearing for speech under everyday listening conditions. This goal was not designed to prevent <u>any</u> hearing loss, as has been the goal of other Federal agencies concerned with general community noise problems, but only that hearing loss which would represent a material impairment--in terms of the worker's safety in the occupational environment, loss of workplace earning potential, and difficulty in communication during and following employment. In essence then, the NIOSH recommendations were to prevent losses from becoming disabling and compensable in nature. Moreover, the proposal contained in the NIOSH criteria document that would eventually reduce the current 8 hour noise limit of 90 dBA to 85 dBA for workplace exposure was designed to reduce by half the number of workers who would display such losses at retirement age.

<u>Formulas for Determining Hearing Loss</u>

Ideally, a person's hearing ability for speech should be measured by presenting a variety of speech material under controlled testing conditions which are typical of everyday listening environments. While there has been progress in devising such tests to determine hearing impairment for compensation purposes, they have not yet been adopted as standardized measures. Questions persist, for example, about the possible unfamiliarity of the speech test items, the vocabulary limitations of the person being tested, the need for extensive equipment, and special training to administer and score the speech tests. Generally hearing is measured through simple tests of pure tone sensitivity as portrayed in audiograms, and relates the threshold hearing levels for certain test tone frequencies to the ability to hear and understand speech.

Formulas relating hearing of pure tones to hearing for speech are numerous and date back nearly 50 years[11-15]. Perhaps the most popular of those used was one developed by the Subcommittee on Noise of the American Academy of Opthalmology and Otolaryngology and adopted by the American Medical Association in 1961[15]. This formula simply averaged the hearing threshold levels for frequencies 500, 1000 and 2000 Hertz and defined an average of 25 dB (decibels) (re ANSI) (15 dB re ASA) as the "low fence" or point of beginning hearing handicap for speech reception. Impairment was assumed to increase linearly above this average level at the rate of 1 1/2 percent per decibel in excess of the "low fence." Thus, 100% or total hearing impairment was reached for an average value of 93 dB (ANSI) (82 dB ASA) in this formulation. Calculations for hearing impairment in both ears were also included in this formulation, the better ear being weighted 5 times more heavily than the poorer ear in making such determinations.

After reviewing data available to NIOSH in preparation of the noise criteria document, the Institute recommended a change in the AMA definition of hearing impairment. Specifically, it substituted the frequency 3000 Hz for 500 Hz to better define hearing impairment. In a quiet environment, there is a high correlation between the average hearing levels at 500, 1000, and 2000 Hz and speech perception results[18,19]. However, the need to include 3000 Hz was shown to be critical when such reception took place under more realistic listening conditions, such as those involving background noise, interrupted speech, or reverberation[16,17]. More recently published data since the issuance of the NIOSH criteria document continue to emphasize the importance of high frequency hearing for discrimination of speech under everyday listening conditions[20-22]. It remains NIOSH's position that if pure tone hearing loss is to be used to estimate impairment to speech reception, then hearing loss at 3000 Hz should be included in the formula. On March 7, 1977, the Division of Employment Compensation of the Department of Labor, in agreement with NIOSH, adopted the 1000, 2000, 3000 Hz averaging formula for compensation purposes using 25 dB as the "low fence" in defining hearing loss claims for Federal employees.

Much controversy remains about the average pure tone hearing levels corresponding to the "low fence", or point of beginning impairment, and the ratings of hearing loss disability given average values exceeding this "low fence." Suggested values for "low fence" generally range from 15 to 35 decibels (ANSI) depending upon the particular frequencies being used in the averaging calculation, and disability ratings vary from 1 to 2% per decibel in excess of the designed low fence. NIOSH still considers that 25 dB (ANSI) as averaged for frequencies 1000, 2000 and 3000 is a reasonable starting point for assessing hearing handicap.

Binaural Hearing Impairment

NIOSH agrees with the need for a weighting formula for calculating binaural (both ear) hearing impairment. It has long been recognized that total loss of hearing in one ear does not reduce one's overall hearing capacity by 50% if hearing in the other ear is essentially normal. The Office of Workers' Compensation Program follows the currently accepted practice of weighting the better ear 5 times more than the poorer one in binaural hearing impairment determinations. Although data to support this specific amount of weighting are obscure, NIOSH considers it an acceptable formula. Since the hearing levels for the left and right ears are quite similar in persons afflicted with occupational hearing loss, this issue may be less important than it seems.

Other Causes of Hearing Loss

We believe that in determining occupational hearing loss some allowance should be made for the deterioration in hearing that occurs through aging (termed presbycusis). Persons having no ear abnormalities and no known history of excessive noise exposure still show losses in hearing level as a function of age. These losses occur at the high frequencies that are also readily affected by noise exposure. The NIOSH noise criteria document contains a set of presbycusis values that could be utilized in adjusting claims for occupational hearing loss due to noise or other causes. The Office of Workers' Compensation Program does not allow for such deductions at the present time.

Although excessive exposure to occupational noise is generally regarded as the most serious hearing loss hazard, other workplace factors can also lead to compensable hearing disorders. The presence of airborne contaminants can lead to ear infections, with hearing loss as a secondary consequence of this disease process. Coal workers, for example, due to extreme dust exposures may be especially vulnerable to ear infections and resultant hearing disorders. A NIOSH survey of hearing loss among these workers did report a higher than normal incidence of otoscopic ear abnormalities[6]. Blows on the head and certain medications may also result in severe hearing impairment. These factors and other considerations make diagnostic evaluations of hearing disorders a complicated process. Off-job noise exposures may also be sufficiently severe in many instances to aggravate occupational hearing loss[24].

The NIOSH criteria document recommended pre-employment as well as follow-up audiograms to identify early those persons with existing hearing impairment as well as those who show unusual sensitivity to noise. Such data provide for better job placement and may protect the employer from the liability for the total amount of hearing loss, given a subsequent compensation claim. Unless a job has unusually critical communication requirements, however, placement problems should not be too formidable. While an average hearing level of 25 dB for frequencies 1000, 2000 and 3000 Hertz defines the threshold for a beginning handicap, truly significant losses for speech reception are not generally seen until the average loss for these frequencies exceeds 55 dB. Job tasks necessitating stringent hearing requirements would need to be identified and could be accepted as medical criteria in issues for worker selection.

<u>Compensation Issues</u>

The question of how much to compensate a bonafide case of total or partial occupationally-related disability in one or both ears is a difficult one. The 50 states differ greatly in the amount they award for hearing disabilities[23]. Total loss of hearing in both ears is worth $4500 in Rhode Island and $63,000 in the District of Columbia. According to the latest formulation of the Office of Workers' Compensation Program, a GS-13 worker with dependents, showing total loss of hearing in both ears, could be eligible for a total award of $70,116. Why the same disability in one jurisdiction should be worth 14 times more than that in another and still more for a Federal employee is an enigma. Clearly, there is need for a more uniform and equitable basis for arriving at compensation benefits for hearing loss, recognizing that to some wage earners such impairment may mean greater losses in employment opportunities and earnings than to others.

In summary we offer the following recommendations for determining occupational hearing loss for compensation purposes. In some instances, they reaffirm practices already in effect by the Office of Workers' Compensation Programs.

(1) The present formula recommended by NIOSH for defining a compensable hearing loss, (i.e., average losses for three frequencies of 1000, 2000, and 3000 Hz must exceed a "low fence" of 25 decibels (re ANSI) should be retained.

(2) The presently accepted scheme for weighting evident hearing loss in the better, more sensitive ear, 5 times more that the poorer ear should be retained.

(3) A deduction for presbycusis to take account of some natural loss in hearing via aging should be used for computing disability from occupational hearing loss. The NIOSH criteria document offers a set of presbycusis values that could be utilized for such purposes.

(4) Employers should provide pre-employment and follow-up audiograms to identify workers with existing hearing impairment and monitor any hearing loss that develops during the course of employment. Results of such audiograms should be used in determining each employer's liability for hearing loss claims when a worker has changed jobs.

(5) Employment should not arbitrarily be denied to an individual because of a hearing deficiency established by a pre-employment audiogram. However, critical listening requirements for specified jobs should be established based on performance and safety considerations.

(6) Measurements of noise and other environmental factors in the working environment should also be included as part of the evidence for determining the validity of a compensation claim for occupational noise-induced hearing loss.

(7) Consideration should be given to developing an equitable, uniform basis for hearing loss compensation awards reflecting the differing loss potentials that such disability may have for persons whose hearing is important to their vocations.

Mr. Chairman, my colleagues and I will be pleased to answer any questions you or Members of the Subcommittee may have.

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OCCUPATIONAL DISEASES

A Guide to Their Recognition

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OSCILLATORY VIBRATIONS

Terry L. Henderson, Ph.D., Derek E. Dunn, Ph.D., R. J. Nozza, M.A., and Don Wasserman, M.S.E.E.

Research and study continue in efforts to verify noise tolerance limits for protecting human hearing. The effects of different vibration conditions for causing pain and injury or illness to individuals exposed are also under study. The following sections offer a broad overview of present findings in relation to recognizing the occupational origin of certain symptoms due to exposure to oscillatory vibrations.

Advanced mechanization has created excessive noise in many occupations. Various aspects of noise exposure have been correlated with hearing loss, and proposed exposure limits for protecting against hearing loss have been developed.

DESCRIPTION

Noise is generally identified as unwanted sound. The word "sound" itself can be used to mean either a physical pressure oscillation (alternate increases and decreases in normal atmospheric pressure caused by a rapidly vibrating object) or the resulting subjective auditory sensation that occurs when the hearing mechanism is stimulated. The rate of vibration of the object corresponds to the frequency of sound expressed in Hertz (Hz), the unit of frequency corresponding to one vibration cycle per second.

The frequency range of audible sounds for healthy young ears is usually considered to extend from 20 to 20,000 Hz although there is evidence to indicate that the range of man's hearing extends beyond these limits. The simplest type of sound, called a pure tone, consists of a very regular oscillation at a single frequency. This sound may be produced by a tuning fork or electric means. In contrast, music, speech, and noise, each containing a collection of different frequency sounds, are called complex sounds.

The pattern of distribution of acoustical energy at the various frequencies is referred to as the *spectrum* of the sound. The frequencies comprising speech are found principally between 250 and 3,000 Hz. This is, therefore, considered to be the most important range of frequencies, since hearing loss for speech sounds would handicap the individual in most daily activities.

MEASUREMENT

Sound pressure level (SPL) measurements are based upon the average (root mean square) amplitude of the pressure changes constituting the sound stimulus and are directly related to the intensity or energy characteristics of the sound. The unit of measurement is the "decibel," abbreviated "dB." Instruments are readily available for measurement of SPL. When measuring intense noises, one usually uses the "A-weighting" feature that is incorporated into most sound level meters in order to partially simulate the response to the human ear. If so, then the abbreviation for decibel is modified to "dB(A)."

NOISE

The process of measuring the environmental sound level presents problems because the sound levels are apt to be variable and to change rapidly with time as well as with position. Although negative dB levels (below zero) are theoretically possible, and extremely high levels may be encountered at the exhaust of a turbojet or rocket, with rare exception the environmental sound level will lie within the range of 20 to 125 dB(A).

Doubling the number of noisy machines in a room does not double the sound level (it will probably increase by only about 3 dB). The sound level in a room will depend upon 1) the total amount of sound energy being produced within the room or leaking into the room from the outside, 2) how thoroughly the room is enclosed, i.e., how well sound is prevented from leaking out, 3) how acoustically absorbent the walls and contents of the room are, 4) the size and shape of the room, and 5) the distance to the sound source and to reflecting or shielding surfaces.

TYPES

Noise, commonly defined as unwanted sound, covers the range of sound which is implicated in harmful effects. Noise can be classified into many different types, including wide-band noise, narrow-band noise, and impulse noise. To describe the spectrum of a noise the audible frequency range is usually divided into eight frequency bands, each one-octave wide, and SPL measurements are made in each band using a special sound level meter. A wide-band noise is one where the acoustical energy is distributed over a large range of frequencies. Examples of wide-band noise can be found in the weaving room of a textile mill and in jet aircraft operations.

Narrow-band noises, with most of their energy confined to a narrow range of frequencies, normally produce a definite pitch sensation. For a true narrow-band noise, only a single octave band will contain a significant SPL. The noise caused by a circular saw, planer, or other power cutting tools is occasionally of the narrow-band type, but usually there is some spreading of the acoustic energy to several of the octave bands.

The impulse type of noise consists of transient pulses, occurring in repetitive or nonrepetitive fashion. The operation of a rivet gun or a pneumatic hammer usually produces repetitive impulse noise. The firing of a gun is an example of non-repetitive impulse noise.

HARMFUL EFFECTS

Exposure to intense noise causes hearing losses which may be temporary, permanent, or a combination of the two. These impairments are reflected by elevated thresholds of audibility for discrete frequency sounds, with the increase in dB required to hear such sounds being used as a measure of the loss. Temporary hearing losses, also called auditory fatigue, represent threshold losses which are recoverable after a period of time away from the noise. Such losses may occur after only a few minutes of exposure to intense noise. With prolonged and repeated exposures (months or years) to the same noise level, there may be only partial recovery of the threshold losses, the residual loss being indicative of a developing permanent hearing impairment.

Temporary

Temporary hearing impairment has been extensively studied in relation to various conditions of noise exposure. Findings include the following:

1) Typical industrial noise exposures produce the largest temporary hearing losses at test frequencies of 4,000 and 6,000 Hz. The actual pattern of loss depends upon the spectrum of the noise itself. The greatest portion of the loss occurs within the first 2 hours of exposure. Recovery from such losses is greatest within 1 or 2 hours after exposure.

2) The amount of temporary hearing loss from a given amount of noise varies considerably from individual to individual. For example, losses at a given frequency due to noise intensities of 100 dB(A) may range from 0 to more than 30 dB.

3) Low frequency noise, below 300 Hz, must be considerably more intense than middle or high frequency noise to produce significant threshold losses.

4) Considerably fewer temporary hearing losses result from intermittent than from continuous noise exposure, even though the total amount of noise exposure is the same in both instances.

Permanent

The permanent hearing loss that is seen in workers who have been exposed to noise daily for a period of many years is very similar to the pattern of temporary hearing loss except that the permanent loss is not recoverable and does not respond to any known treatment or cure.

Exposure to intense noise, however, is only one cause of permanent hearing damage. Other causes may be disease, mechanical injury, and use of drugs. The time and nature of onset of the loss, the pattern of hearing loss for different frequencies, the findings of an otologic examination and medical history are factors in determining whether a case of permanent hearing damage might be due to noise exposure or other causes. Once these causes have been excluded from the etiology of hearing damage, the losses attributable to the aging process (presbycusis) must be considered. Curves showing the usual deterioration in hearing with increasing age are used to differentiate the amount of hearing loss due to noise exposure from that due to the aging process.

Figure 6 illustrates median shifts in hearing acuity of a group of noise-exposed jute weavers. (Corrections for the effects of aging were used to determine the effects due solely to noise.)

Although no direct physiological link has been established between temporary and permanent hearing loss, the similarities have led to some tentative conclusions, including the notion that permanent loss represents the long term accumulation of residual losses from incomplete recovery to repeated, daily temporary hearing loss. Evidence from noise-exposed groups of workers shows that permanent threshold losses caused by noise initially appear in the region 3,000 to 6,000 Hz and are most prominent at 4,000 Hz. With continued exposure, the losses in hearing become greater and occur at frequencies above and below the 3,000 to 6,000 Hz range until eventually losses are shown at most frequencies.

The losses in hearing due to exposure to intense occupational noise (105 dB(A) or above) tend to reach a plateau at certain frequencies (most notably 4,000 Hz) after about 10 years of exposure; further losses in hearing at the frequency then develop more slowly, and may be accounted for substantially by the aging process. Since the hearing loss for such frequencies which result from a 10-year exposure to noise appears to approximate the temporary hearing loss resulting from a single day's exposure, it is possible that, when validated, the use of temporary threshold losses as a susceptibility index for predicting permanent noise-induced hearing losses may be a useful screening tool.

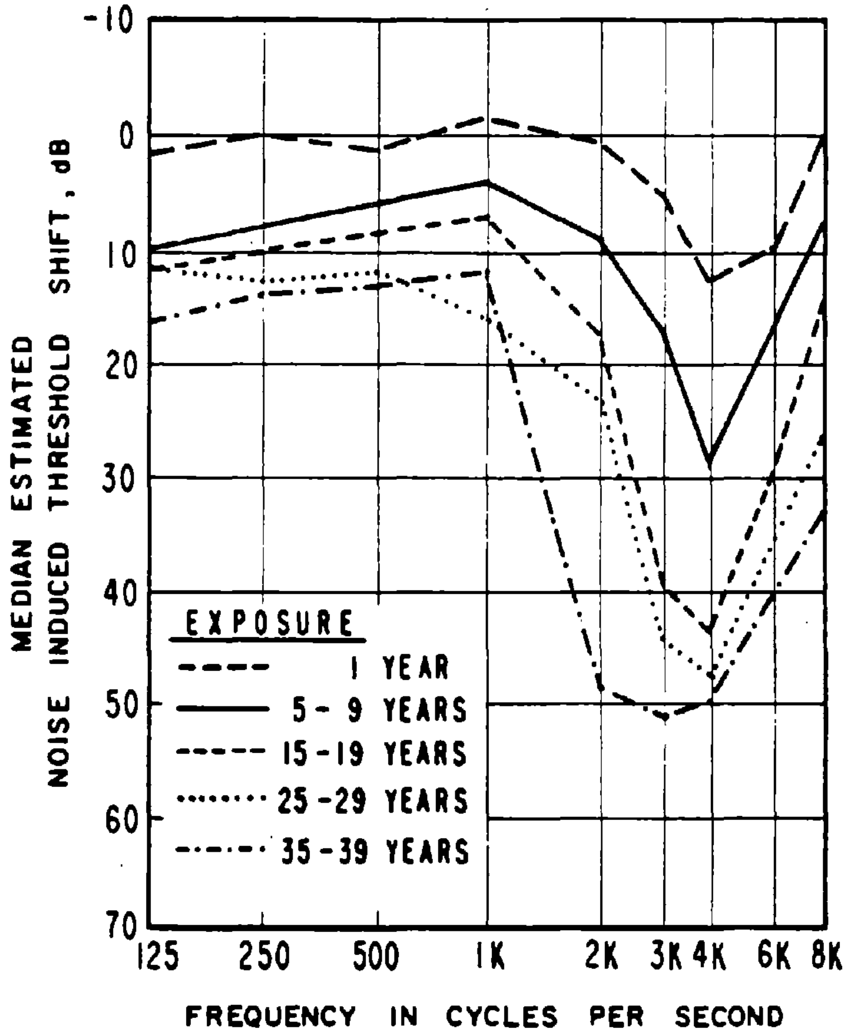

Figure 6. **Median permanent threshold shifts in hearing levels as a function of exposure years to jute weaving noise. (Data taken from Taylor, et al. [Ref. Taylor W. A., A. Mair, and W. Burns. 1965. Study of noise and hearing in jute weaving. J. Acoust. Soc. Am. 48:524-530]). (Figure from Criteria for a Recommended Standard . . . Occupational Exposure to Noise.)**

Communications Interference

Noise which is not intense enough to cause hearing damage may still disrupt speech communication and the hearing of other desired sounds. Such disruptions will affect performance on those jobs which depend upon reliable speech communication and may contribute to job stress. More important, however, is the fact that the inability to hear commands or danger signals due to excessive noise increases the probability of severe accidents. Ear protectors are no solution because when they are worn, shouting will be necessary for communication, which may lead to hoarseness, and communication is still not assured.

Physiologic Effects

Physiologic reactions to a noise of sudden onset represent a typical startle pattern. There is a rise in blood pressure, an increase in sweating, an increase in heart rate, changes in breathing, and sharp contractions of the muscles over the whole body. These changes are often regarded as an emergency reaction of the body, increasing the effectiveness of any muscular exertion which may be required. However desirable in emergencies, these changes are not desirable for long periods since they could interfere with other necessary activities. Fortunately, these physiologic reactions subside with repeated presentations of the noise.

For performance on a task to remain unimpaired by noise, man must exert greater effort than would be necessary under quiet conditions. When measures of energy expenditure — for example, oxygen consumption and heart rate — are made during the early stages of work under noisy conditions they show variations which are indicative of increased effort. Measurements in later stages under continued exposure, however, show responses return to their normal level.

RECOMMENDED PROTECTIVE METHODS

Those controlling the individual company hearing conservation activities should insure that no permanent hearing loss occurs among the employees.

PERMISSIBLE EXPOSURE LIMITS

Noise dose limits are now required for workplaces to minimize hearing loss from occupational exposure. Although louder noise is allowed for brief periods during the workday, the mandatory noise level limitation is 90 dB(A) for 8 hours exposure. As noted earlier, the "(A)" denotes the use of the A-weighting scale of the sound level meter, which takes into account the relative effectiveness of different frequencies of the noise spectrum in producing hearing damage.

AUDIOMETRIC TESTING

Since early noise-induced losses almost always occur at frequencies slightly above the so-called speech range, substantial impairments in hearing can occur without the individual's being aware of it. Impairments in the perception of speech may not become noticeable until losses for the speech frequencies are 20 dB or more.

An effective audiometric testing program can be provided by utilizing either company personnel and equipment or the services of an independent organization on a contract basis.

The audiometric test is a simple means of evaluating a person's hearing acuity. An audiogram, which is a graph of hearing vs. frequency, is the product of an audometric evaluation. An audiogram should be obtained periodically for any employee working in a noise-related job in order to monitor changes, if any, in hearing status. The initial or baseline audiogram should be obtained prior to an employee's first day on a new assignment. The evaluation supplies the employer with not only valuable information concerning the worker's ability to perform the job safely and competently, but also documentation of the employee's hearing at that date in the event of a future claim for hearing loss compensation.

In addition, the aging process, possible use of ototoxic drugs, off-the-job activities, over-susceptibility to noise, past medical problems, and former work experiences, must all be taken into consideration in a comprehensive hearing evaluation. Most pertinent information can be acquired when a full history is obtained at the preemployment examination and supplemented at periodic tests.

Audiometric monitoring can be effective in protecting the worker from incurring a significant hearing loss. Changes in a worker's hearing may indicate that the hearing conservation program is failing. Noise measurements should be made to determine if there has been a change in the noise levels or work patterns since the last noise survey was done. A change in the noise level may be due to a modification of manufacturing technique, a malfunction of existing equipment, or the addition of new equipment. One should then determine if the noise control measures are actually providing the attenuation anticipated and whether administrative measures to reduce individual exposure doses are adequate. It is very important to confirm that proper conditions of fit are being maintained for any ear protectors being used. The worker may need a refresher course on the use of ear protectors and the benefits of cooperating with the hearing conservation effort. Unless the changes revealed by the audiometric monitoring lead to effective correction action, further hearing losses will not be prevented and the monitoring program will have been rendered valueless.

When hearing testing is done, certain conventions must be followed. A suitable quiet environment for the tests is particularly important. The equipment used must meet fairly rigid specifications. The testing apparatus (audiometer, head phones, test room) must be calibrated and procedure must be standardized in order to insure the comparability of a test taken at one place and time with those done at some later time in perhaps other workplaces.

The equipment is not the only component that needs careful attention in audiometric testing. The person responsible for the monitoring program must be properly trained in the use of the audiometer, the meaning of the audiogram, dealing with the industrial worker, and in the providing of ear protection.

EAR PROTECTION DEVICES

The subject of fitting of ear protection deserves special attention. There are a variety of different types of devices available, each requiring special procedures and considerations for obtaining proper fit. An employee may require several trials with different types and sizes of plugs before a suitable combination of comfort and protection is obtained. The decibel attenuation data provided by the manufacturer do not reflect the inherent physical property of the device, but rather an optimistic level of performance to be expected under good conditions of fit, which cannot usually be maintained in the workplace.

POTENTIAL OCCUPATIONAL EXPOSURES

Noise is the most widespread of all the occupational exposures and may be encountered in almost any occupation.

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MORBIDITY AND MORTALITY WEEKLY REPORT

Perspectives in Disease Prevention and Health Promotion

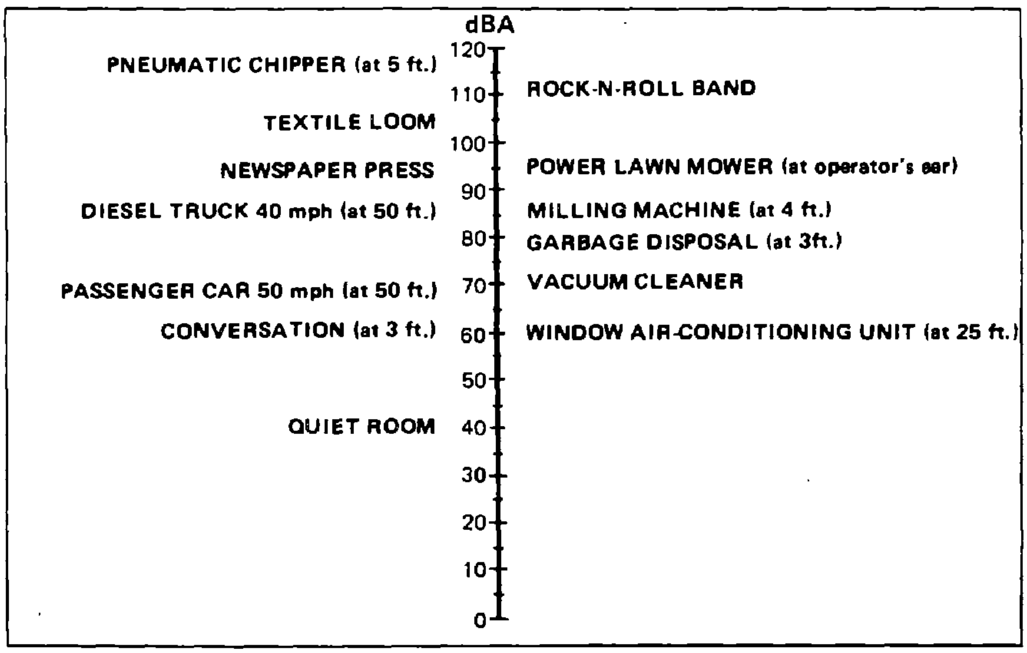
Leading Work-Related Diseases and Injuries — United States

The National Institute for Occupational Safety and Health (NIOSH) has developed a suggested list of 10 leading work-related diseases and injuries (1). *The first seven categories have been described* (1-7); *this article focuses on the eighth category, noise-induced loss of hearing.*

NOISE-INDUCED LOSS OF HEARING

Occupational deafness was first documented among metalworkers in the sixteenth century (*8*). Since then, workers have experienced excessive hearing loss in many occupations associated with noise. Typical occupational and nonoccupational noise levels are shown in Figure 1. Noise-induced loss of hearing is an irreversible, sensorineural condition that progresses with exposure. Although hearing ability declines with age (presbycusis) in all populations, exposure

FIGURE 1. Typical A-weighted noise levels in decibels (dBA)*



*The decibel is a logarithmic measure of sound intensity; the "A-weighted scale" is used to weight the various frequency components of the noise to approximate the response of the human ear.

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Leading Work-Related Diseases and Injuries – Continued

to noise produces hearing loss higher than that resulting from the natural aging process; this is caused by damage to nerve cells of the inner ear (cochlea) and, unlike some conductive hearing disorders, cannot be treated medically.

While loss of hearing may result from a single exposure to a very brief impulse noise or explosion, such traumatic losses are rare. In most cases, noise-induced hearing loss is insidious. Typically, it begins to develop at 4,000 hertz (Hz, or cycles per second) in the hearing range of 20 Hz to 20,000 Hz and spreads to lower and higher frequencies. Often, material impairment has occurred before the condition is clearly recognized.

Such impairment is usually severe enough to permanently affect a person's ability to hear and understand speech under everyday conditions. Although the primary frequencies of human speech range from 200 Hz to 2,000 Hz, research has shown that the consonant sounds, which enable people to distinguish words such as "fish" from "fist," have still higher frequency components. As a result, an average hearing threshold (lowest audible sound level) at separate frequencies of 1,000 Hz, 2,000 Hz, and 3,000 Hz is used widely to define material impairment caused by noise (*10,11*).

Recent estimates by the Occupational Safety and Health Administration (OSHA) indicate that about 9,400,000 U.S. production workers (7,900,000 active and 1,500,000 retired) either now work or have worked in industrial locations where noise-exposure levels are 80 decibels (dBA) or higher. This estimate includes most noisy workplaces in the United States, except agricultural, mining, construction, transportation, and government (Table 1) (*11*). At exposure levels below 80 decibels (weighted to the approximate response of the human ear, dBA), an increased risk of hearing loss caused by occupational noise has not been found. Based on the average hearing threshold level at 1,000 Hz, 2,000 Hz, and 3,000 Hz, OSHA estimated that 1,624,000 (17%) production workers have at least mild hearing loss resulting from their occupational noise exposures; 1,060,000 (11%) have material hearing impairment; and 473,000 (5%) have moderate to severe impairment (Table 2) (*11*). These estimates generally agree with NIOSH survey findings, which indicate that one-fourth of persons 55 years of age or older who have been exposed over their working lifetime to an average of about 90 dBA have developed a material hearing impairment caused by occupational noise exposure (*10,12*). An estimated $835 million will be paid in workers' compensation claims for occupational hearing impairment for the 10-year period 1978-1987 (*13*).

Reported by Physical Agents Effects Br, Div of Biomedical and Behavioral Science, National Institute for Occupational Safety and Health, CDC.

Editorial Note: Occupational noise-induced loss of hearing is preventable. In its 1990 objectives for the nation, the U.S. Public Health Service set an objective that "By 1990, the prevalence of occupational noise-induced hearing loss should be reduced to 415,000 cases" (*14*). This objective relates to the number of cases of hearing loss that result in moderate to severe impairment (Table 2). However, it is important to note that if the number of moderate to severe impairments is reduced, the number of mild hearing loss and of material impairments

TABLE 1. Distribution of 9,368,000 production workers who had noise-exposure levels of 80 dBA or greater* — United States

Noise-exposure level (dBA)	No. workers
80-85	3,305,000
86-90	2,656,000
91-95	1,936,000
96-100	965,000
>100	506,000

*From the 1981 OSHA Final Regulatory Analysis for the Hearing Conservation Amendment.

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would be reduced proportionately. OSHA has estimated that within 10 years, the number of cases of noise-induced hearing impairment can be reduced by 20% if all workers exposed to noise levels higher than 85 dBA wear personal hearing protectors (earplugs or muffs) and receive on the average 15 dBA noise reduction (*11*). However, this estimate hinges on effective use of hearing protectors to an extent that has not yet been demonstrated for all workers. NIOSH field investigations of industrial workers who routinely use earplugs indicate average noise reduction ranging from 7 dBA to 20 dBA, depending on the type of plug used (*15*).

A noise-control/hearing-conservation program is the most important step in eliminating occupational hearing loss. Such a program must include:

1. Reduction of noise through engineering controls and the purchase of new, noise-engineered equipment.
2. Proper fit of personal hearing-protection devices.
3. Education of workers and managers about certain characteristics of noise-induced loss of hearing (e.g., irreversible, subtle in onset, psychologically distressing).
4. Proper periodic audiometric testing and notification of workers who are developing hearing loss.
5. Visible commitment of management and workers to the program.

The joint efforts of management, labor, and health-care providers are needed to establish effective hearing-conservation programs in industry. All interested groups must work together to achieve the goal of protecting workers' hearing.

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TABLE 2. Hearing levels (dB) of 9,368,000 production workers who had noise-exposure levels of 80 dBA or greater* — United States

Hearing threshold level (1,000, 2,000, and 3,000 Hz)	Cumulative cases (%)	Expected cases† (%)	Excess cases§ (%)
>15 dB (mild hearing loss)	3,735,000 (40%)	2,111,000 (23%)	1,624,000 (17%)
>25 dB (material hearing impairment)	2,025,000 (22%)	965,000 (10%)	1,060,000 (11%)
>40 dB (moderate to severe hearing impairment)	718,000 (8%)	245,000 (3%)	473,000 (5%)

*From the OSHA 1981 Final Regulatory Analysis for the Hearing Conservation Amendment.

†Based on hearing levels of a nationwide sample of adults in U.S. Public Health Service hearing surveys.

§Cumulative cases minus expected cases.

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Proposed National Strategy for the Prevention of Noise-Induced Hearing Loss

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health
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Introduction

This document, *A Proposed National Strategy for the Prevention of Noise-Induced Hearing Loss*, summarizes what actions need to be taken to prevent occupational noise-induced hearing loss. It was developed in 1985 at a conference sponsored by the National Institute for Occupational Safety and Health (NIOSH) and The Association of Schools of Public Health (ASPH), which brought together over 50 expert panelists and 450 other occupational safety and health professionals.

In addition to the strategy for noise-induced hearing loss, NIOSH and ASPH have published strategies for the other nine leading occupational diseases and injuries: occupational lung diseases, musculoskeletal injuries, occupational cancers, severe occupational traumatic injuries, occupational cardiovascular diseases, disorders of reproduction, neurotoxic disorders, dermatological conditions and psychological disorders.

The proposed strategies were originally published in a two volume set, *Proposed National Strategies for the Prevention of Leading Work-Related Diseases and Injuries, Part 1 and Part 2*. These proposed strategies are not to be considered as final statements of policy of NIOSH, The Association of Schools of Public Health, or of any agency or individual who was involved. Hopefully, they will be used in the quest to prevent disease and injury in the workplace.

To learn of the availability of the complete texts of Part 1 and Part 2, or to obtain additional copies of this or other Strategies, contact NIOSH Publications, 4676 Columbia Parkway, Cincinnati, Ohio 45226. Telephone (513) 533-8287.

A Proposed National Strategy For the Prevention of Noise-Induced Hearing Loss

I. Introduction

The causal relationship between noise and hearing loss has been observed anecdotally for centuries (*1*). Sir Francis Lord Bacon commented on sudden hearing loss resulting from loud sounds and also referred to Pliny the Elder's *Natural History*, which described the hearing problems experienced by persons who lived near waterfalls along the Nile in the first century A.D. (*2*). Reports that actually described occupational noise-induced hearing loss began to appear 100 years after Bacon's writings. In 1713, Ramazzini published "De Morbis Artificum Diatriba" in which he commented on copper workers who suffered hearing loss as a result of hammering on metal (*3*). In the 1800s, Thomas Barr documented noise-induced hearing loss (NIHL) in his studies of boilermakers in Britain, and Fosbroke described blacksmiths' deafness from continued exposure to noise (*4,5*). In this century, hearing loss sustained by many soldiers in World War II was the impetus for increased research activity into the health effects of noise, development of noise-control techniques, and the promulgation and enforcement of noise regulations.

Although exposure to nonoccupational or recreational noise may be severe enough to cause hearing loss, workers exposed to high levels of industrial noise show still greater NIHL than that found in workers who are not exposed to noise in the workplace (*6*). Workers exposed to excessive noise both on and off the job are in double jeopardy.

Increased regulatory activity in the United States between 1969 and 1972 to protect workers from hazardous noise exposure gave reason for optimism that noise-induced hearing loss in the workplace would no longer be a major health problem.

The first noise standard issued by the federal government was the Walsh-Healey Public Contracts Act in 1969 (*7*). This Act covered only workers on federally funded projects. Shortly afterwards, the Occupational Safety and Health Act of 1970 (OSH Act) required that workers be protected from various occupational hazards (*8*). In 1971, under authority of the OSH Act, the Occupational Safety and Health Administration (OSHA) promulgated an occupational noise standard for manufacturing establishments engaged in interstate commerce (*9*).

That noise standard set a maximum exposure of 90 dBA time-weighted average (TWA) for an 8-hour period with a 5 dB trading ratio (i.e., for each 5 dBA increase, the permissible exposure time is reduced by 50%; conversely, a reduction of 5 dBA allows a doubling of the exposure duration). Peak levels of impulse/impact noise are not permitted above 140 dB. When worker exposures exceed the levels allowed, an effective hearing conservation program is required. The noise standard is still the legal basis for determining whether a worker is exposed to potentially hazardous noise.

In 1972, the Noise Control Act assigned responsibility to the Environmental Protection Agency for identifying safe levels of environmental noise, labeling noise-producing devices, and informing the public of the hazards of noise exposure (*10*).. NIOSH published its Recommended Standard for Occupational Exposure to Noise in 1972 (*11*), recommending an 8-hour TWA of 85 dBA instead of 90 dBA. NIOSH still recommends an 85 dBA TWA for 8 hours with the 5 dB trading ratio, but there is no indication that this recommendation will be adopted.

In 1983, OSHA promulgated a hearing conservation amendment to the 1971 noise standard (*12*). Although the Amendment does not change the permissible exposure level of 90 dBA TWA, it defines an effective hearing conservation program and requires that such a program be started if workers have an exposure of 85 dBA TWA or greater. A hearing conservation program must include an assessment of noise exposure, audiometric tests of exposed workers, noise abatement and/or administrative controls, maintenance of records on noise and hearing data, availability of hearing protectors, and employee training and education.

A variety of regulations have been established to conserve the hearing of noise-exposed workers not covered by the noise standard. Consequently, most workers exposed to potentially hazardous noise, except those in agriculture, have some regulations protecting their hearing. However, the separate regulations are neither uniform across worker groups nor as rigorous as the 1971 noise standard with its 1983 amendment for manufacturing industries.

Some momentum generated by regulations of the early 1970s has been lost, as evidenced by a steady decline in the number of yearly plant inspections by Government enforcement agencies. This reduced number of factory inspections results in fewer citations for violations of the noise standard because many worksites not in compliance with the noise regulations are not checked. In addition, there is an apparent unwillingness to extend hearing conservation requirements to cover all noise-exposed workers e.g.,transportation, oil/gas well drilling and servicing, agriculture, construction, mining, etc. (*13*).

Both the public and the private sector have made many contributions to hearing conservation and noise control. Progress in the past 40 years includes 1) an increased establishment of hearing conservation programs, 2) development of improved personal hearing protectors, 3) more precise noise-measurement systems and effective noise-control technology, 4) greater knowledge through research into the effects of noise on the auditory system, and 5) increased education of the public regarding the need and requirements for hearing conservation. Despite this progress, much remains to be done to protect all workers from preventable noise-induced hearing loss.

The prevention strategy presented in this document draws on national expertise to eliminate occupational noise-induced hearing loss. Individual and coordinated efforts are recommended to reduce hearing loss steadily in populations exposed to noise in the workplace until that component of hearing loss attributable to occupational exposure to noise is eliminated.

This document differs in several ways from the other strategy documents aimed at preventing leading work-related diseases and injuries (e.g., psychological disorders, disorders of reproduction, etc.).

- First, some critical issues and recommended actions incorporated in this document were addressed in previous national strategies for the control of noise effects (*14,15*). Hence, this is not the first effort to draft a national plan to alleviate problems of NIHL.

- Second, unlike the other work-related diseases and injuries, noise-induced hearing loss already has federal regulations for its prevention in the workplace. These regulations (mentioned above) specify permissible noise exposures and recommend preventive actions to preserve hearing.

- Third, an array of factors and pathological endpoints underlie many of the other leading work-related diseases and injuries and greatly complicate efforts to develop solid prevention strategies (*16*). Occupational noise-induced hearing loss is caused solely by overexposure to noise in the workplace. The agent and effect are both distinct and measureable. Consequently, the national strategy for preventing noise-induced hearing loss can be more focused than a strategy that must try to define the agents and effects that are noteworthy and in need of control.

II. Examining the Problem

Although no comprehensive epidemiologic data on NIHL exist, an estimated eight million workers in the United States alone are exposed in manufacturing to potentially hazardous average daily levels of occupational noise at 80 dBA and above (*17*). This does not include the more than three million workers in agriculture, construction, forestry, government, mining, transportation, etc., exposed to average daily levels of occupational noise above 85 dBA. The number of workers in these industries exposed to 80-85 dBA is not available (*18,19*).

The number of workers at risk of developing occupational NIHL is necessarily a matter of concern. Twenty-five percent of the workers in manufacturing, transportation, mining, construction, agriculture, and the military are exposed to average daily occupational noise levels above 85 dBA (*13,18*). One U.S. worker in four exposed to 90 dBA noise over a working lifetime will develop a hearing impairment due to occupational noise exposure (*11,20*).

At least one million workers in manufacturing have sustained job-related hearing impairment (defined as greater than a 25-dB average threshold hearing level at 1,2, & 3 kHz), and about half a million of these have moderate to severe hearing impairment (defined as greater than or equal to a 40-dB average threshold hearing level at 1,2, & 3 kHz) (*17*). Workers file compensation claims for hearing losses thought to result from occupational noise exposure, and the cost of these claims for the period 1977-1987 has been estimated at $800 million (*21*). However, the costs of compensation for hearing loss may have been underestimated because the actual rise in claims exceeded the predicted number of claims on which the estimate was based (*22*).

Usually noise-induced hearing loss develops slowly and is not noticed in its early stages (*1,23,24*). This loss results from progressive and subtle destruction of sensory cells in the auditory organ — the cochlea, (*25,26*). Once damaged, these sensory cells cannot repair themselves nor can they be restored through medical intervention. The loss of hearing is, therefore, irreversible and increases in severity with continued exposure to noise.

Although an audiogram is the most accepted clinical measure of hearing sensitivity, the degree of hearing loss recorded in a quiet test setting using individual, pure-tone test signals may not reflect the full extent of auditory handicap experienced under less-than-optimal listening conditions. For example, an audiogram may not predict how a hearing-impaired person will fare when communicating in noisy environments, with someone in a distant room, or over the telephone.

Speech is the primary form of person-to-person communication, and a loss of hearing that impairs this communication produces a social handicap (*27,28*). This handicap is exacerbated by other consequences of hearing impairment, including anxiety and irritability from miscommunication, lowered self esteem, and self-imposed withdrawal from society (*29*). Hearing loss also reduces a person's enjoyment of music and environmental sounds.

The job-related consequences of occupational noise-induced hearing loss may threaten a worker's employment status. An employee with noise-induced hearing loss may face several problems in a noisy production area: communication difficulties (particularly for unexpected messages), which may be exacerbated by wearing hearing protectors; the reduced capacity to monitor changes in machinery sounds; and the inadequate audibility of potential safety hazards (*30-32*). Co-workers and supervisors may interpret these problems as actual reductions in job performance, and the worker may face transfer to another job and reduced employability.

Although the extra-auditory consequences of high-level noise exposure (more stress-induced illness, accidents, irritability, and performance problems) have been reported, noise-induced hearing loss has long been recognized as the primary and most direct health effect of overexposure to noise. If noise exposures can be reduced to prevent NIHL, extra-auditory effects of noise exposure may also be controlled (*33,34*).

III. Prevention Strategy

The proposed strategy for preventing job-related NIHL has three major components: regulation, information dissemination, and research. The first part of the strategy stresses the need to fully enforce and expand current hearing conservation regulations for all noisy workplaces. The second part calls for increased dissemination of information concerning noise control and hearing conservation. The third component elaborates the need for research in hearing science, exposure control, epidemiology, and techniques to increase group acceptance of safe practices.

Major short-term and long-term objectives of the three strategy components are enumerated to define the range and nature of those steps which, if taken, could be effective in preventing NIHL.

A. Regulation

Laws and regulations already exist for controlling occupational noise exposure in manufacturing (*9,12*). The 1971 noise standard and its 1983 amendment are reasonable and feasible approaches to hearing conservation and should be the minimal hearing conservation regulation for all workers. Effective reduction of occupational NIHL requires, however, that federal laws and regulations already in place be fully implemented and enforced by the Department of Labor.

The experience of many professionals engaged in industrial hearing conservation suggests that governmental inspection efforts are inadequate to ensure compliance with the existing noise regulations. These professionals are also concerned that cutbacks in the number of worksite inspections plus the current focus on occurrences of more serious injury/disease is allowing continued exposure to noise conditions harmful to the hearing of workers (*13*). Implementing and enforcing existing legislation and regulations are essential steps in reducing noise-induced hearing loss.

Workers in transportation, oil/gas well drilling and servicing, agriculture (particularly seasonal workers), construction, mining, and the government are either not covered by a noise regulation or are covered by standards less complete than the noise standard and the hearing conservation amendment. Significant progress in reducing NIHL is possible by broadening the 1971 noise standard and its 1983 amendment to cover all occupationally noise-exposed workers and by enforcing those regulations rigorously.

1. Short-term objectives for regulations should include efforts to:

    a. Fully enforce the current federal noise regulations, which provide mechanisms for reducing the risks of hearing loss from exposures to workplace noise. The current regulations limit exposure to 90 dBA for an 8-hour TWA with a 5-dB trading ratio, and hearing conservation programs are required for workers exposed to 85 dBA. A hearing conservation program must include noise measurement, noise abatement and/or administrative controls, audiometric testing, hearing protection, recordkeeping, and employee training.

    b. Require implementation of regulations to include all feasible controls and procedures that can reduce noise levels significantly even if the noise reduction does not comply with the standard.

       OSHA should be encouraged to rescind its Directive Instruction CPL 2.45 CH-11, Guidelines for Noise Enforcement, which does not require engineering controls below 100 dBA and permits the use of hearing protectors if they reduce the noise reaching the ear to a permissible level. The most desirable (and sometimes the most difficult) approach to reducing the risk of occupational NIHL is reducing the level of noise. It is extremely foolhardy to regard hearing protection as a preferred way to limit noise exposures because most employees obtain only half the sound attenuation possible from hearing protectors (*35*). Even with training, some workers fail to obtain maximum benefit from these protectors because they have difficulty adjusting them properly (*36*), or they refuse to wear them because they fear such devices will impair their ability to perform their jobs properly or hear warning signals (*31, 32*). If, however, noise is reduced by engineering or noise control, the limitations of hearing protectors are of less concern.

    c. Require that noise specifications, in the procurement of new equipment on federally funded projects, are consistent with the goal recommended by NIOSH for an 85-dBA environment;

d. Provide recommendations for using clinical data to compute and assess the extent of hearing disability so that the calculation accurately reflects the extent of handicap a person experiences in daily activities. Adopting these recommendations would lead to compensation laws that are scientifically based, uniform nationwide, and equitable.

2. Long-term objectives in regulation should include efforts to:

   a. Extend the 1971 noise standard and its 1983 amendment to cover all industries (agriculture, mining, forestry, transportation, oil/gas well drilling and servicing, construction, etc.) where potentially hazardous noise is present. An estimated three million additional workers will be protected by such an extension.

   b. Recommend that all states compensate workers who suffer job-related, noise-induced hearing loss without regard to whether the loss was sudden or due to accumulated injury over the employment period.

   c. Develop national consensus standards for establishing hearing conservation practices, for evaluating the properties of hearing protectors, and for evaluating product noise levels. These consensus standards will facilitate the implementation of effective hearing conservation programs.

   d. Develop national consensus standards to provide noise labels on newly manufactured equipment through the initiative of appropriate trade associations. These labels will inform the purchaser of the effect this equipment will have on the overall noise environment and will permit a more accurate prediction of the noise exposure an operator will receive.

   e. Reestablish the EPA program to implement the provisions for product noise labeling required in part by the Noise Control Act of 1972. Although the Noise Control Act is still in effect, it currently lies dormant and is not being enforced.

B. Information Dissemination

Although a basic understanding exists of how NIHL occurs and how to prevent its progression, action is needed now to broadly disseminate existing techniques for hearing conservation and noise control. Education and motivation of management and labor alike will speed the implementation of effective preventive measures. This can be fostered by organizing the information into easily usable formats and widely distributing it through trade association newsletters and professional journals.

Employers must be informed and encouraged to reduce the hazard to the workers by controlling noise at the workplace. The technology is not difficult to understand, but little has been done to catalog solutions for noise control from site to site. Systematically identifying and providing noise-control techniques to persons who are seeking solutions will encourage their use. The efforts wasted in solving problems already solved by others would be better directed to other prevention or control activities.

The OSHA Hearing Conservation Amendment prescribes required elements for a hearing conservation program but does not describe how to implement an effective program that includes five interrelated phases: sound surveys, engineering/administrative controls, education, audiometric evaluations, and hearing protection (*37*). If hearing conservation programs are to succeed in preventing NIHL, employers must understand how to organize and operate their programs to make them effective in protecting workers. Workers must also routinely accept and follow through on self-protective actions related to hearing conservation.

1. Short-term objectives for information dissemination should include efforts to:

    a. Develop and disseminate guidelines that show employers and providers of hearing conservation services how to ensure that their hearing conservation programs are effective in preventing NIHL.

    b. Identify existing training materials, curricula, and programs on the hazards of noise and its abatement and catalog them for easy access.

    c. Develop a curriculum model to provide guidelines for buying original equipment that meets federal regulations for sound power output. This model should be made available to schools that train future managers and overseers of safety programs.

    d. Disseminate guidelines showing employers how to use procurement specifications to induce manufacturers to reduce the sound power output of their machinery. If procurers emphasize the importance of quiet design, then manufacturers will give consideration to quiet design when developing new products.

    e. Encourage appropriate educational institutions — particularly the NIOSH-supported Educational Resource Centers — to place more emphasis on noise control and the health effects of noise.

    f. Develop and distribute awards (organizational or governmental) to groups or individuals who make significant contributions in protecting workers from hazardous noise. This will enhance the visibility of efforts to reduce noise and will provide an opportunity to showcase successful hearing conservation strategies.

2. Long-term objectives for information dissemination should include efforts to:

    a. Establish a central clearinghouse for collecting and distributing information about successes and failures in controlling noise exposure and in hearing conservation practices, the organizations to contact for assistance, and current data on the epidemiology of noise-induced hearing loss.

    b. Implement demonstration programs for noise control and/or hearing conservation in those industries and occupations shown by surveillance to be associated with a high incidence of noise and noise-related problems.

    c. Establish and supplement database systems (e.g., NTIS PB88-117916, Industrial Audiometric Data) to include appropriate information on noise control, noise levels, occupational and nonoccupational noise exposures, relevant medical history, etc.

d. Develop curriculum units for effective hearing conservation programs that can be disseminated to train professionals, such as physicians, audiologists, industrial hygienists, safety engineers, mechanical engineers, industrial engineers, and occupational health nurses.

e. Update existing manuals for noise-control products and compendia of engineering solutions as a basis for a catalog of usable, economical, and applied noise controls. Many manuals or compendia are currently geared toward scientists and engineers, and the information should be presented in an understandable way to health and safety practitioners who are not specialists but are responsibile for promoting safe and healthful workplaces.

f. Promote and support national and international standards for noise control, hearing conservation practices, and product noise control through such organizations as the American National Standards Institute, the Acoustical Society of America, the American Society of Mechanical Engineers, the American Society for Testing Materials, and the Society of Automotive Engineers.

g. Inform the public of the need to protect hearing to avoid the biologic and social consequences of exposure to noise. All forms of the media should be used. In addition, information shall be distributed to large public gatherings, such as state and local fairs, health conventions, etc.

h. Develop education programs and promote existing programs in primary and secondary schools and in universities for teaching the basic science of sound, including its hazards, and methods of self-protection.

i. Encourage developers of the credit-card-sized records for personal health information — sometimes called "smart cards" — to include space for information on hearing sensitivity.

C. Research

Information is currently lacking on the incidence of NIHL. Regular and accurate statistics must be collected to assess the magnitude of the problem and to monitor the effect of various prevention/intervention efforts. Although the burden of data collection and reporting should be kept at manageable levels, information must be acquired to effectively and efficiently direct resources that will reduce occupational NIHL. Some much-needed data can be obtained through national health surveys, such as the National Health And Nutrition Examination Survey (NHANES).

OSHA required (1983 Amendment to the Noise Standard) that simultaneous, continuous, intermittent, and impulsive sounds between 80 dBA and 130 dBA be measured together and evaluated to determine if the noise exposure exceeds an 8-hour TWA level of 85 dBA (*12*). If this approach is used to assess noise exposure, then errors may lead to the overexposure of workers (*38-40*). The method was adopted partly because of a lack of scientific data on which to base a more accurate technique.

Research is needed to better define the hazardous parameters of impulse/impact noise and the relative hazard posed by "quiet" periods that interrupt the noise exposure. An understanding of how hearing loss is produced by the various parameters of impulse/impact noise and non-steady-state noise will permit development of accurate, damage-risk criteria for protecting workers' hearing.

Although implementating the regulation and information-dissemination components of this strategy will have an immediate impact on reducing NIHL, the following research issues should be pursued to keep the outlined strategies up-to-date and effective.

1. Short-term objectives in the area of research should include efforts to:

   a. Keep a central file on some gauge of hearing capacity (either a standard threshold shift or some other measure of hearing) to permit a yearly monitoring of hearing in the workplace.

   b. Review annual reports from OSHA on the number of plants that have hearing conservation programs in effect and the number of employees covered by these programs. These data should be arranged using the Standard Industrial Classification.

   c. Analyze data collected under the OSHA Hearing Conservation Amendment to evaluate the effectiveness of regulations.

   d. Recommend a standard format for entering audiometric data on a computer to facilitate the exchange of information and to begin developing a national audiometric data base. The NHANES III Hearing Assessment Format is a model that should be evaluated.

2. Long-term objectives in the area of research should include efforts to:

   a. Collect hearing data for populations not exposed to occupational noise as a baseline for comparing the hearing of groups exposed to noise. Norms should be established as a function of geographic region, sex, race, age, etc.

   b. Perform additional field evaluations of personal hearing-protection devices to document their real-world performance. Better laboratory and/or field procedures can then be devised to improve the accuracy of standardized attenuation tests in estimating field performance.

   c. Conduct research to better define the relative hazard of different kinds of noise (impulse, impact, intermittent, etc.).

   d. Determine through investigations the degree to which noise interacts with other agents in the work environment (solvents, metals, prescription drugs, etc.) to affect hearing. Although some drugs and industrial solvents have been established as ototoxic (*41-43*), recent data indicate that noise exposure combined with exposure to drugs or industrial solvents may result in more hearing loss than would be predicted from a summation of individual effects (*44-46*). In light of these findings, further investigation of possible potentiation of occupational hearing loss by chemical agents seems warranted.

   e. Assess the impact of noise-induced hearing loss and hearing protection through research on speech communication and the identification of warning signals.

f. Develop audiometric indicators for data from both individuals and groups to identify noise-sensitive workers who need additional protection and hearing conservation programs or practices that may not be fully effective.

g. Develop improved hearing-protection devices that would provide clearer and more natural audition. Special consideration may be necessary for individuals with hearing losses or for users of hearing aids.

h. Develop a time-weighted-average noise descriptor for employees exposed to noise on an irregular basis, such as an 8-hour or longer workday once a week, or one week per month.

i. Describe the physiologic mechanisms associated with noise-induced hearing loss (e.g., energy integration, degenerative and recuperative processes, etc.). These studies may clarify which noise parameters contribute the most to damage in the ear.

j. Investigate the changes in non-auditory effects (accident rate, absenteeism, productivity, fatigue, etc.) that have been noted after hearing conservation programs have been instituted (*47*). These findings need confirmation.

IV. Summary

Noise-induced hearing loss is a progressive injury that develops as a result of cumulative exposure. Both its beginning and its progression can be prevented by limiting noise exposure. Because no remedial action can completely restore or compensate for hearing capacity that has been lost, prevention is the preferred strategy. The two major approaches for preventing occupational NIHL are limiting noise in the workplace and encouraging affected individuals and involved organizations to accept and practice effective hearing conservation techniques.

The diverse talents and expertise of many individuals and groups are needed to address the objectives proposed in this document. A consensus on all the proposed objectives for reducing noise-induced hearing loss is not necessary, but all persons concerned with the issues raised must address those objectives to which they can effectively contribute. These efforts, taken together, could make attainment of the desired goal possible: a significant reduction and ultimate elimination of occupationally related, noise-induced hearing loss.

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NUMBER OF WORKERS EXPOSED TO OCCUPATIONAL NOISE

John R. Franks, Ph.D.

It is common knowledge that there is noise associated with almost every work activity, whether the activity is making steel, mining coal, or hammering nails. The causal relationship between workplace noise and hearing loss has been observed anecdotally for centuries. In the early 1700s, Ramazzini[1] commented on copper workers who had hearing loss from hammering on metal. The terms "boilermaker's ear" and "tinshop ear" have been used to describe occupational noise-induced hearing loss since the 1800s.[2] The hearing loss experienced by many soldiers during World War II provided the impetus to increase research activity in the area of the effects of noise on health and in the development of noise control and abatement techniques.

However, what is not common knowledge is the prevalence of occupational noise-induced hearing loss, the amount of noise produced, and the number of workers exposed to noise levels that could be considered hazardous to hearing. Although the Williams-Steiger Occupational Safety and Health Act of 1970[3] mandated that all workers be safeguarded from occupational hazards, including noise, it did not specify the means to determine how many workers were exposed to hazards or how best to protect them.

In 1971, the Occupational Safety and Heatlh Administration (OSHA) promulgated an occupational noise standard for manufacturing establishments. The noise standard required that protection against the effects of noise be provided when sound levels exceed the permissible noise exposure level. The permissible noise exposure level was set to 90 dBA for 8 hours of exposure and allowed to change by 5 dB for every doubling or halving of time. The standard also set maximum exposure for continuous noise at 115 dBA, regardless of duration, and limited impulsive or impact noise to a maximum of 140 dB peak sound pressure level. The noise standard required that an effective hearing conservation program be initiated when the recommended exposure levels were exceeded, but did not specify what constituted an effective hearing conservation program.

In 1983 OSHA promulgated the

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Hearing Conservation Amendment[4] to the noise standard, which specified what a hearing conservation program should be. Only the manufacturing industries group and the utilities industry (hereinafter referred to as the manufacturing group) are covered. Separate regulations have been established, to a lesser extent, for industries such as mining, construction, and transportation. Amended regulations have been established for the federal government, which are more strict. Most workers, with the exception of those in agriculture, are covered by some type of noise standard and hearing conservation regulation.

By law, it was necessary to determine the economic impact of the Hearing Conservation Amendment would make on industry before the noise standard could be amended. It was important to determine the number of workers who were exposed to hazardous workplace noise, in which industries they worked, and the distribution of noise levels amoung the workers. During the years the Hearing Conservation Amendment was in preparation, three surveys were conducted that included estimates of the numbers of workers exposed to various noise levels. Each survey used a different method to establish the level of noise in the sampled workplaces, different criteria for sampling, and different criteria for calculating the size of the work force. Although these surveys have provided much valuable information, they have not answered many important questions concerning the prevalence of work-related hearing loss and the effectiveness of hearing conservation programs in reducing hearing loss.

NATIONAL OCCUPATIONAL HAZARD SURVEY

Between 1974 and 1978, the prevalence of noise exposure in industry and the availability of employer-provided hearing conservation programs were among the issues of focus of the National Occupational Hazard Survey (NOHS).[5] A team of surveyors was sent throughout the nation. They carried sound level meters with them and made short-term noise measurements in each sampled plant in a variety of locations. Those workers exposed to noise levels of 85 dBA or greater were identified. The workers were considered to be noise exposed if the noise was associated with routine operation of the facility regardless of the duration of the noise.

The surveyors also recorded other information. They recorded whether the noise was continuous or impulse-impact noise. They established whether a hearing conservation program, which included hearing testing, was available in the plant. They did not establish the number of workers in a plant using hearing-protection, nor did they establish the number of workers in a plant that might have hearing loss, noise-induced or otherwise.

Displayed in Figure 1 are the NOHS figures for total number of workers and the percentage of workers exposed for each major industry grouping and for the various industries within the manufacturing group. Clearly, the manufacturing group had the greatest number of workers and the greatest percentage of workers exposed to 85 dBA or greater noise. (See Table 1 for tabularization of these data.)

These data were used by OSHA[4] for the initial determination of:

1. The number of plants within manufacturing group industries.
2. The number of plants within manufacturing group industries with workers exposed to noise: continuous and impulse-impact.
3. The number of workers within manufacturing group industries.
4. The number of workers within manufacturing group industries exposed to noise: continuous and impulse-impact.

BOLT, BERANEK, AND NEWMAN STUDY

In 1976, Bolt, Beranek, and Newman (BBN), under contract from the United States Department of Labor, performed a

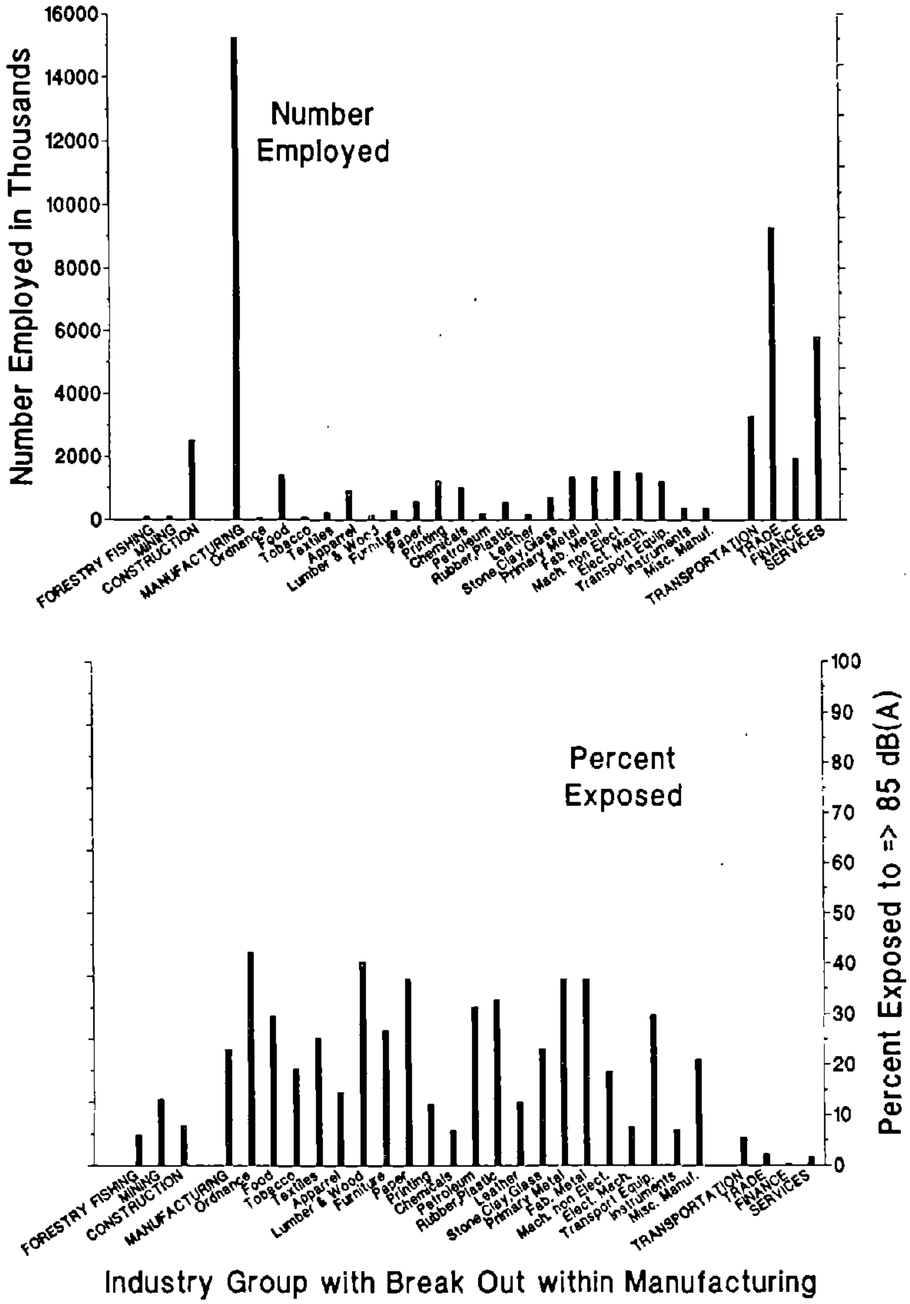

Figure 1. The numbers and percentages of workers exposed to noise levels 85 dBA or greater by industry group and by industry within the manufacturing group based on data from the National Occupational Hazard Survey.[5]

study of the impact of noise on society and a study on the impact of the amendment on business.[6] A summary of their findings was used by OSHA in the Final Regulatory Analysis of the Hearing Conservation Amendment.[4] Included was an estimate of the percentage of workers exposed to noise levels of greater than 80, 85, 90, 95, and 100 dB. BBN used $L_{eq(8)}$ as its criteria for measurement of noise. Thus, for a worker to be considered exposed to an 85 $L_{eq(8)}$, the average exposure for 8 hours had to equal

TABLE 1. Numbers and Percentages of Workers Exposed to Noise Levels 85 dBA or Greater by Industry Group and by Industry Within the Manufacturing Group*

Industry Group	*Employment Levels (Thousands)*	*Percent Exposed*
Fishing and Forestry	82	6.1
Mining	82	13.0
Construction	2,535	7.9
Manufacturing (total)	15,241	23.0
Ordnance	33	42.1
Food	1,402	29.7
Tobacco	80	19.2
Textile	232	25.3
Apparel	918	14.4
Lumber and wood	161	40.4
Furniture	295.	26.8
Paper	571	36.8
Printing	1,239	12.2
Chemical	996	7.0
Petroleum	195	31.4
Rubber and Plastic	534	32.7
Leather	155	12.6
Stone, clay and glass	700	23.1
Primary metals	1,347	37.0
Fabricated metals	1,350	37.0
Machines, nonelectric	1,539	18.6
Electrical machines	1,501	7.6
Transportation equipment	1,224	29.7
Instruments	386	7.1
Miscellaneous manufacturing	384	21.0
Transportation	3,311	5.6
Trade	9,283	2.2
Finance	1,946	0.4
Services	5,803	1.6

*Based on data from the National Occupational Hazard Survey[5]

85 dBA. This is similar to the concept of time weighted average (TWA) used by OSHA in the final version of the Hearing Conservation Amendment.

BBN estimated the number of workers exposed in each industrial group based on their sampling techniques. Although the study was performed in 1976, OSHA applied the percentage of exposed workers based on 1979 employment levels for each industry with the manufacturing group are displayed in Figure 2. The total percentages of workers exposed to 80 dBA or more of noise are shown at the top of each bar. By estimates of BBN, 53 percent of all workers in the manufacturing group were exposed to noise levels in excess of 80 dBA. BBN also estimated that 34 percent of these workers were exposed to noise levels in excess of 85 dBA, 19 percent to levels greater than 90 dBA, and 8 percent were exposed to levels greater than 95 dBA. The top seven industries with the greatest percent of exposed workers to levels of 85 dBA or greater were lumber and wood, textiles, petroleum, utilities, primary metals, printing, and paper. According to the 1979 estimates of the Bureau of Labor Statistics used by OSHA,[4] these industries employed 30 percent of the production workers in the manufacturing group plus utilities. (See Table 2 for tabularization of these data.)

BOOZ, ALLEN, AND HAMILTON STUDY

Booz, Allen, and Hamilton (BAH) were commissioned in 1983 by the Office of Regulatory Analysis of OSHA to evaluate the technical and economic impact of set-

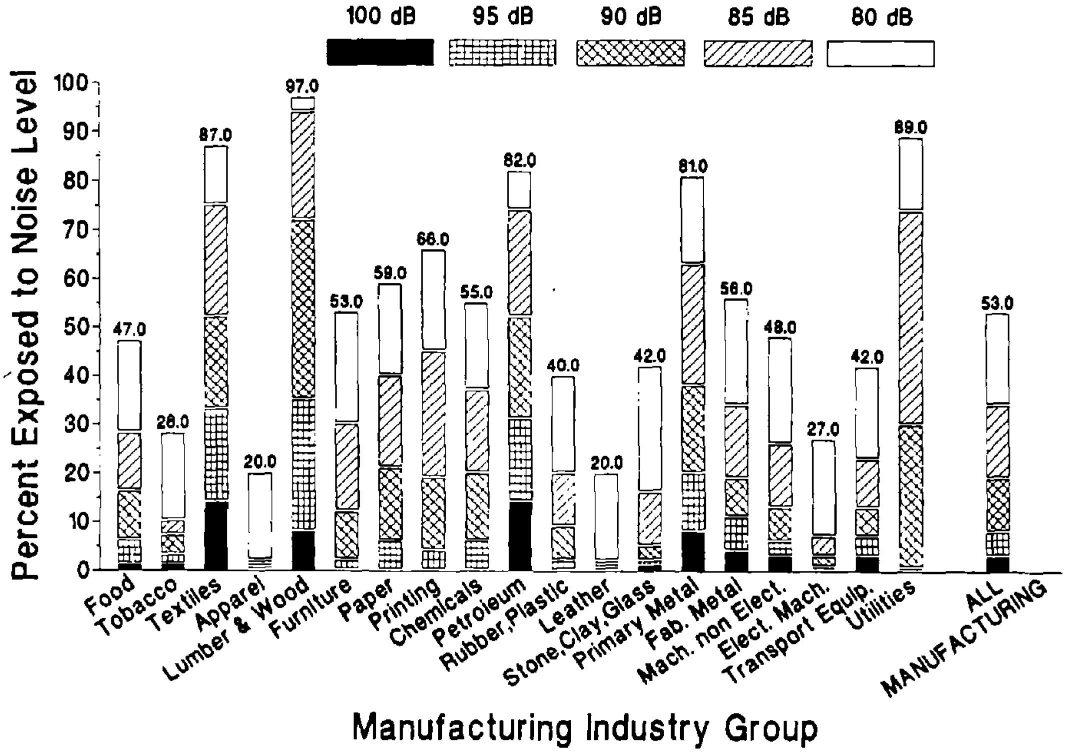

Figure 2. The percentage of workers for each industry within the manufacturing group exposed to levels of 80, 85, 90, 95, and 100 dBA based on data from Bolt, Beranek, and Newman.[6]

TABLE 2. Percentage of Noise-Exposed Workers for Each Industry Within the Manufacturing Group*

	Estimated Percentage of Exposed Workers				
Manufacturing Group	***≥80 dB***	***≥85 dB***	***≥90 dB***	***≥95 dB***	***≥100 dB***
Manufacturing (Total)	53.1	35.4	19.3	8.3	2.9
Food	47.0	28.0	16.0	6.0	1.0
Tobacco	28.0	10.0	7.0	3.0	1.0
Textiles	87.0	75.0	52.0	33.0	14.0
Apparel	20.0	1.0	0.0	0.0	0.0
Lumber and wood	97.0	94.0	72.0	35.0	8.0
Furniture	53.0	30.0	12.0	2.0	0.0
Paper	59.0	40.0	21.0	6.0	0.4
Printing	66.0	45.0	19.0	4.0	0.0
Chemicals	55.0	37.0	20.0	6.0	0.1
Petroleum	82.0	74.0	52.0	31.0	14.0
Rubber and plastic	40.0	20.0	9.0	2.0	0.3
Leather	20.0	1.0	0.0	0.0	0.0
Stone, clay and glass	42.0	16.0	5.0	2.0	1.0
Primary metals	81.0	63.0	38.0	20.0	0.8
Fabricated metals	56.0	34.0	19.0	11.0	4.0
Machines, nonelectric	48.0	26.0	13.0	6.0	3.0
Electric machines	27.0	7.0	2.5	0.5	0.1
Transportation equipment	42.0	23.0	13.0	7.0	3.0
Utilities	89.0	74.0	30.0	0.0	0.0

*Based on data from Bolt, Beranek, and Newman[6] ting an alternative noise standard.[7] In particular, they evaluated setting the allowable exposure levels to 85 versus 90 dBA. They also produced estimates of the percentage of the work force exposed to noise levels exceeding 85, 90, 95, and 100 dBA.

Unlike the NOHS and BBN surveys, BAH relied on reports from either the sampled industries or from acoustic consultants. The noise level criteria were established as permissible exposure levels (PEL) for 8 hours, the same as TWA or $L_{eq(8)}$. Data were gathered extensively for worker exposures at the PEL of 90 dBA. Estimates of numbers of exposed workers at PELs of 85, 95, and 100 dBA were calculated based on the distribution of noise in key sampling industries. Percentage of workers exposed to each PEL was applied to 1979 employment figures from the Bureau of Labor Statistics. For those industries within the manufacturing group lacking sufficient data, BAH used the BBN estimates.

The BAH study was designed to produce three key estimates:

1. The percentage of workers within the manufacturing group exposed to TWAs that exceeded PELs of 85, 90, 95, and 100 dBA
2. The percentage of workers who would be exposed to the same PELs after the implementation of engineering and noise controls set to reduce workplace noise to PELs of 85, 90, 95, and 100 dBA
3. The average cost per worker to bring each worker under a PEL of 85, 90, 95, or 100 dB.

All projections were based on a macroeconomic model that was simulated for a PEL of 90 dBA. The values of 85, 95, and 100 dBA were based on extrapolations from the model.

CROSS-SURVEY COMPARISONS

The three surveys were performed within a few years of each other and are currently the best estimates with which we have to work. Although determining the number of workers exposed to noise was not the main purpose of any of these surveys, each made an estimate of the percentage of workers exposed to noise. Figure 3 displays the NOHS, BBN, and BAH estimates of percentage of workers exposed to noise levels of 85 dBA or greater for each industry within the manufacturing group. The total percentage exposed for all industry groups is also shown.

The figure shows that some industries, such as ordnance, instruments, and miscellaneous manufacturing, were sampled only by the NOHS survey. In some cases the BAH estimates of number of exposed workers are highest, in others the BBN estimates are highest, and in others the NOHS estimates are highest. For all of the manufacturing group, the BAH estimates of number of exposed workers are highest. This is interesting considering that the NOHS survey considered a worker exposed if subjected to any noise of 85 dBA or greater, whereas both the BBN and BAH surveys took into account the time of exposure so that the BBN and BAH values can be considered as average daily exposures. Given the differences in methods, one would have predicted that the NOHS estimates would be the highest and that the BBN and BAH estimates would be similar. (See Table 3 for tabularization of these data.)

COST OF PROTECTING WORKERS

The three surveys used different strategies and different references for estimates of the total workforce size. Because of this, and because a decade has passed, in 1987 it is not possible to provide an estimate of the number of noise-exposed workers within a 5 percent (700,000 worker) confidence interval. If the BBN estimates from 1976 are applied to the 1985 work force, then the number of noise-exposed workers would be as follows: 7,449,000 exposed to levels of 80 dBA or greater; 4,685,000 exposed to levels of 85 dBA or greater; 2,707,000 exposed to levels of 90 dBA or greater; 1,164,000 exposed to levels of 95 dBA or

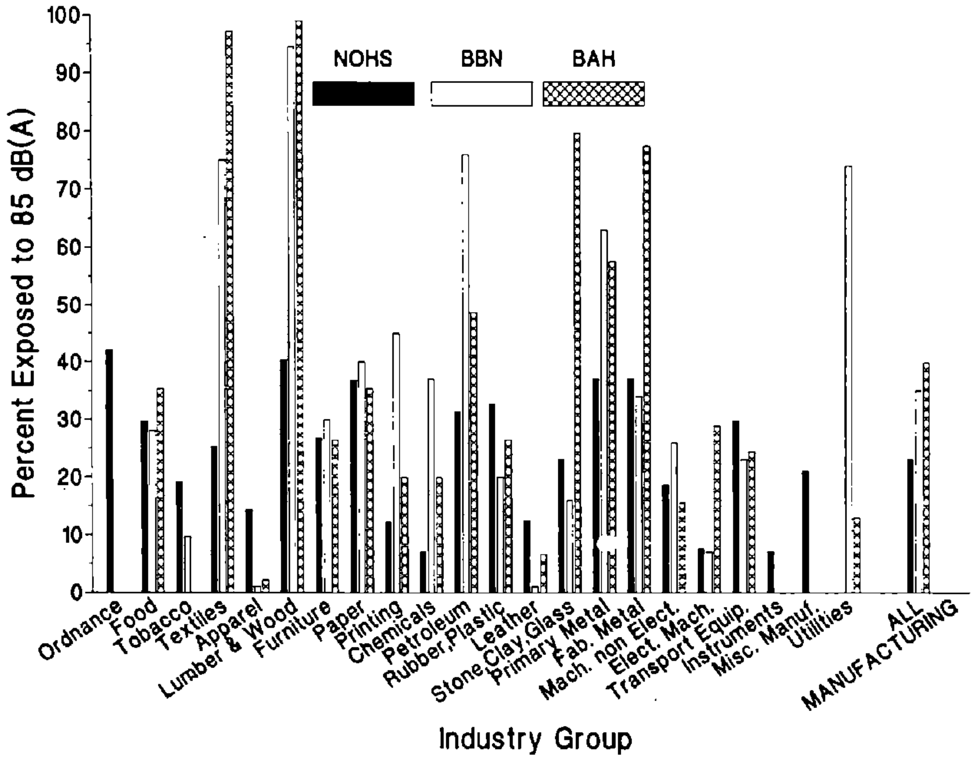

Figure 3. Comparison of National Occupational Hazard Survey (NOHS), Bolt, Beranek and Newman (BBN),[6] and Booz, Allen, and Hamilton (BAH)[7] estimates of numbers of workers for each industry within the manufacturing group exposed to noise levels equal to or exceeding 85 dBA.

TABLE 3. Comparison of National Occupational Hazard Survey (NOHS),[5] Bolt, Beranek, and Newman (BBN),[6] and Booz, Allen and Hamilton (BAH)[7] Estimates of Numbers of Workers for Each Industry Within the Manufacturing Group Exposed to Noise Levels 85 dBa or Greater

	Estimated Percentage of Exposed Workers		
Manufacturing Group	***NOHS***	***BBN***	***BAH***
Manufacturing (Total)	23.0	35.0	39.8
Ordnance	42.1	—	—
Food	29.7	28.0	35.4
Tobacco	19.2	9.7	—
Textiles	25.3	75.0	97.2
Apparel	14.4	1.0	2.2
Lumber and wood	40.4	94.0	99.0
Furniture	26.8	30.0	26.5
Paper	36.8	40.0	35.4
Printing	12.2	45.0	19.9
Chemicals	7.0	37.0	19.9
Petroleum	31.4	76.0	48.7
Rubber and plastic	32.7	20.0	26.5
Leather	12.6	1.0	6.6
Stone, clay and glass	23.1	16.0	79.6
Primary metals	37.0	63.0	57.5
Fabricated metals	37.0	34.0	77.4
Machines, nonelectric	18.6	26.0	15.5
Electric machines	7.6	7.0	28.8
Transportation equipment	29.7	23.0	24.0
Instruments	7.1	—	—
Miscellaneous manufacturing	21.0	—	—
Utilities	—	74.0	13.0

greater; and 407,000 exposed to levels of 100 dBA or greater. It is precarious to extrapolate from data gathered before 1976 and from employment figures from 1979, in order to predict conditions in 1987. Many industries that have been very noisy have become quieter through the process of retooling. Some noisy areas of manufacturing, such as primary metals, have had reduction in production workers of 25 percent between 1980 and 1985. Other areas of manufacturing have increased the number of production workers, such as printing and publishing, with an increase of 21 percent.[8]

If the number of noise-affected workers cannot be accurately estimated, then neither can the cost of protecting the hearing of those workers. The 12 percent discrepancy between the NOHS estimate and that of the BAH estimate can be converted to production workers based on 1979 BLS figures[6] and is equal to 1,788,000 workers. Using OSHAs 1981 estimate of $53 cost per worker for a hearing conservation program, the difference between the NOHS and BAH estimates translates to $94,764,000 of uncertainty per year. Using the BAH estimate of $1351 per worker to achieve a PEL of 90 dBA by implementation of administrative and engineering controls, the difference was $2,415,880 in 1979.

The Hearing Conservation Amendment has been in effect since 1983. If all covered industries were in total compliance with the Amendment, it could be expected that 34.4 percent of the work force would be included in hearing conservation programs and that about 20 percent would be using hearing protection, using the BBN figures on which the amendment relied. There is no means by which to determine if this is the case or not in 1988. There are anecdotes about companies that place all workers in the hearing conservation program and require the use of hearing protection for workers exposed to noise levels greater than 85 dBA, regardless of time of exposure. There are also anecdotes, with an occasional OSHA citation for support, about companies that have yet to begin any type of hearing conservation program even for noise levels approaching 100 dBA.

Since the initial surveys were performed, there also has been a shift in the work force.[8] Figure 4 displays the number of production workers for the industry groups for the years 1975 and 1985. Between 1979 and 1985, the percentage of the total production work force within the manufacturing group decreased from 28 to 21 percent, but the total number of production workers within all industry groups increased by 29 percent. The largest growth was 52 percent in the service group, whereas the manufacturing group grew by only 2 percent. The initial NOHS[5] survey indicated that less than 5 percent of the service group workers were noise exposed. It may be possible that the number of exposed workers will remain constant or decrease as employment emphasis shifts from manufacturing to trade, finance, and service. It may also be possible that the noise exposure of workers in the service group has changed so that the percentage of exposed workers is higher than NOHS estimated.

DETERMINING THE AVAILABILITY OF HEARING CONSERVATION PROGRAMS

The availability of periodic audiometric testing programs was a topic of NOHS.[5] By NOHS estimates, 37 percent of all workers exposed to continuous noise received some type of periodic audiometric testing. Within the manufacturing group, 40 percent of all workers exposed to continuous noise received periodic audiometric testing, with the tobacco industry providing the highest coverage at 97 percent and the apparel industry providing the lowest coverage at 1 percent. The industry group providing the highest percentage with audiometric testing was the mining group at 100 percent, and the lowest coverage for noise-exposed workers was wholesale and retail trade at 3 percent. The quality of these audiograms or the use to which they are put is not known.

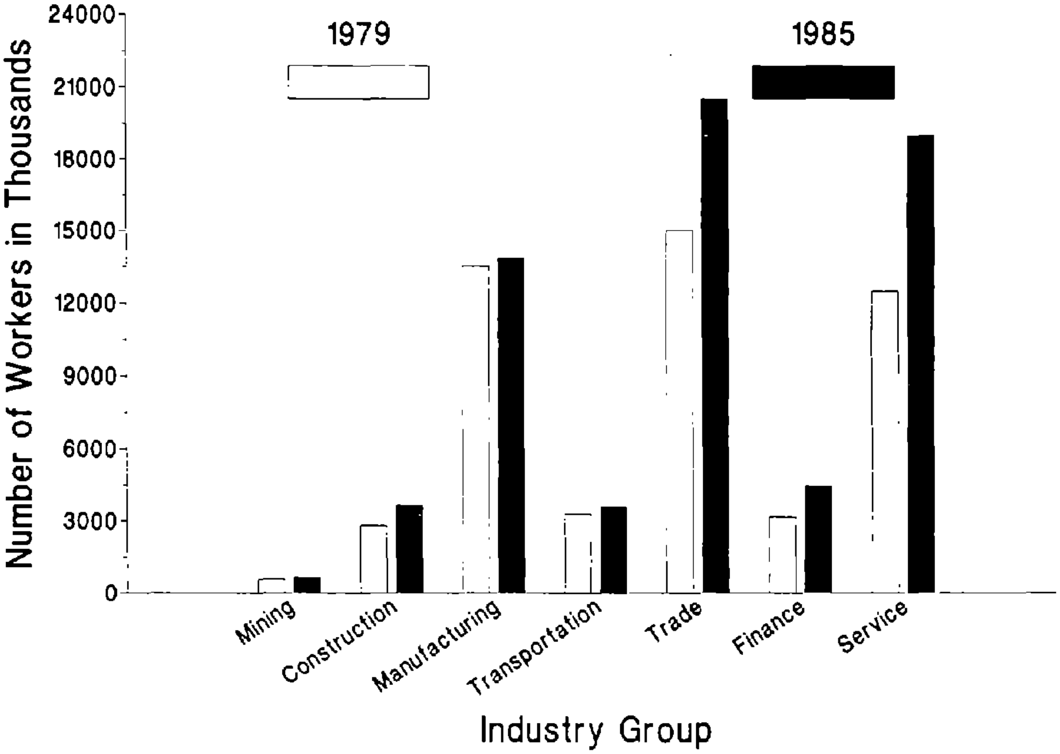

Figure 4. Comparison of the number of production workers in each industry group for the years 1979 and 1985.

TABLE 4. Comparison of the number of production workers in each industry group for the years 1979 and 1985

	Employment Levels (Thousands)		
Industry Group	*1979*	*1985*	*Change (Percent)*
Mining	571	661	16
Construction	2,808	3,639	30
Manufacturing	13,533	13,845	2
Transportation	3,281	3,602	10
Trade	15,024	20,481	36
Finance	3,173	4,425	39
Services	12,479	18,966	52
Total	50,869	65,619	29

There is no national audiometric data base or national registry. Some of the companies that contributed data bases to the American National Standards Institute (ANSI) S12.12 Working Group had been providing audiometric testing before any type of regulation. Although 100 percent of the exposed workers in the mining group received periodic audiometric testing, the audiograms were either filed away or thrown away so that it is not possible to construct a data base for miners. The same problem with estimating the number of workers exposed to noise exists with estimating the percentage of exposed workers receiving periodic audiometric testing. Knowing the number of workers receiving periodic audiometric testing would not completely solve the problem. The Hearing Conservation Amendment requires far more from a hearing conservation program than periodic audiometric testing, and there are no survey data available for the additional aspects.

EVALUATING THE EFFECTIVENESS OF HEARING CONSERVATION PROGRAMS

The effectiveness of hearing conservation programs and hearing protection in preventing noise-induced hearing loss is not measurable for the entire work force. ANSI S12.12 Working Group, Effectiveness of Hearing Conservation Programs,[9] has obtained records from 22 companies. Contained in these records are noise exposure levels for almost all types of workers. These data bases were acquired from companies with active hearing conservation programs. There is no information about what percentage of each company's work force is noise exposed. The sample is inadequate to allow extrapolation to the work force at large. Nonetheless, the ANSI S12.12. Working Group has provided an analysis strategy that will evaluate the effectiveness of a hearing conservation program once a data base is established for a given industry or company.

The effectiveness of hearing protection as used in the field has been evaluated.[10,11] General results show that actual protection is less than the hearing protector specifications would predict. There have been no comprehensive studies, nor sufficient numbers of smaller studies, to evaluate the effectiveness of all types of hearing protectors as worn by the worker. There has been some indication that hearing protectors do not offer the same protection from impulse-impact noise as they do from continuous noise.[12]

An effective hearing conservation program is one in which few, if any, workers experience standard threshold shift (STS) as defined by the Hearing Conservation Amendment. The Bureau of Labor Statistics has the responsibility for maintaining records of occupational illnesses, injuries, and death. Each company in the United States is required to provide this information on OSHA Form 200. STS, as defined by the Hearing Conservation Amendment, has not been recorded as an occupational illness or injury; therefore, the number of workers experiencing STS is not an available statistic.

SUMMARY

At present, the following questions remain:

1. What is the distribution of impulse-impact noise and continuous noise in industries covered by the Hearing Conservation Amendment?
2. What is the distribution of impulse-impact noise and continuous noise in industries not covered by the Hearing Conservation Amendment (such as petrochemicals, construction, transportation, mining, agriculture, trade, finance, and service groups)?
3. What percentage of workers are exposed to noise levels greater than 80, 85, 90, 95, and 100 dBA in each industry?
4. Of the workers exposed to noise levels greater than 85 or 90 dBA, what percentage are using hearing protection? What percentage are receiving adequate protection?
5. Of the workers exposed to noise levels greater than 85 dBA, what percentage are included in hearing conservation programs that meet the minimal standards of the Hearing Conservation Amendment?
6. Of the workers exposed to noise levels greater than 85 dBA, what percentage of those included in hearing conservation programs are experiencing STS?

The lack of answers to these questions limits the accuracy of any assessment of the magnitude of occupational noise-induced hearing loss. The ability to direct efforts effectively to reduce the incidence and severity of work-related hearing loss is also reduced. It is imperative that surveys of noise, the incidence of hearing loss, and hearing conservation programs be designed properly and carried out periodically if progress (or lack of progress) in preserving worker's hearing is to be assessed.

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ARTICLE FOUR

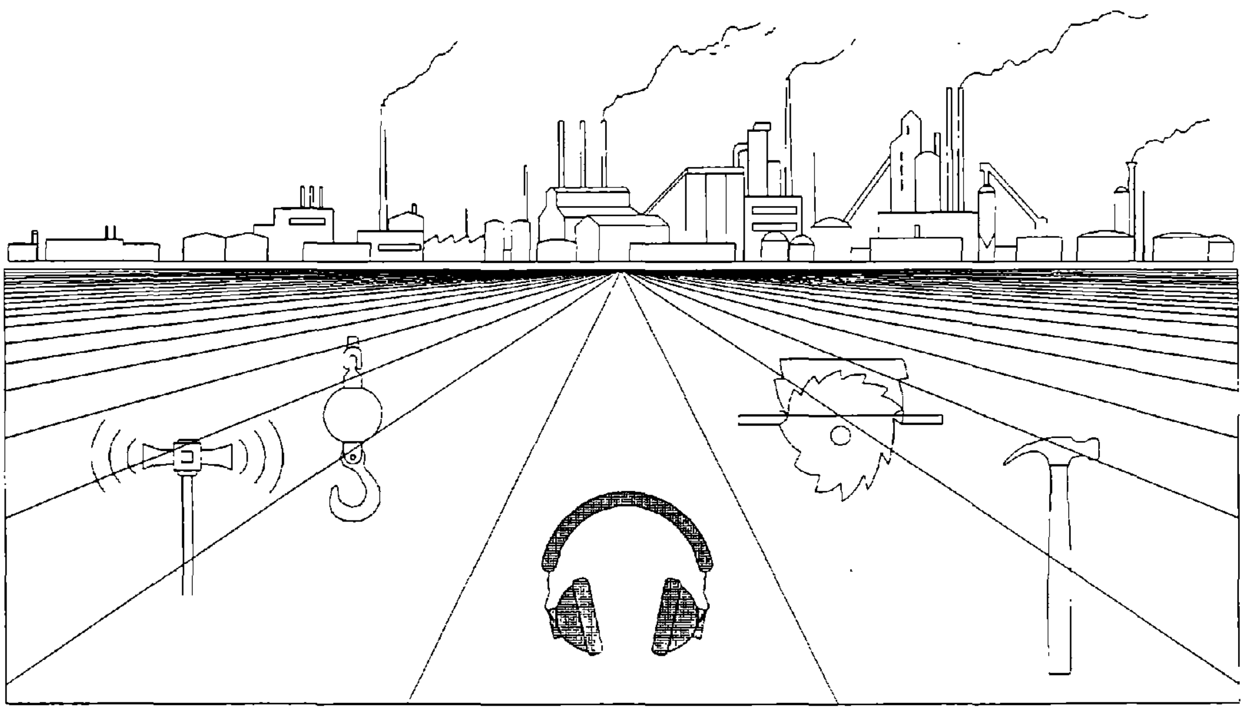
SELF-ASSESSMENT QUESTIONS

1. The industry group showing the highest incidence of noise-exposed workers according to the National Occupational Hazard Survey was:
   (a) mining
   (b) manufacturing
   (c) trade (retail and wholesale)
   (d) service
2. Consider selecting an industry group to set up a model hearing conservation program. According to BBN statistics, how many have more than 10 percent incidence of exposure to noise levels equal to or greater than 95 dBA? Are all of those industries presently covered by the Hearing Conservation Amendment?
   (a) all
   (b) one
   (c) three
   (d) five
3. Suppose that a new survey of the incidence of noise exposure and occupational noise-induced hearing loss were released that had a sampling error of only 1.5 percent. How would that compare to the NOHS, BBN, and BAH surveys?
   (a) more workers exposed
   (b) fewer workers exposed
   (c) less accurate estimates
   (d) more accurate estimates
4. Which industry group is not covered by any type of noise control?

(a) mining
(b) manufacturing
(c) agriculture
(d) service

5. The industry group that showed the slowest growth rate between 1979 and 1985 was:
(a) manufacturing
(b) mining
(c) construction
(d) finance

a practical guide to effective hearing conservation programs in the workplace



U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health

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A PRACTICAL GUIDE TO EFFECTIVE HEARING CONSERVATION PROGRAMS IN THE WORKPLACE

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DISCLAIMER

Mention of the names of any company or product does not constitute endorsement by the National Institute for Occupational Safety and Health.

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PREFACE

Hearing conservation programs can comply with the letter of the law (meaning the OSHA standard) and yet be ineffective in preventing work-related noise-induced hearing loss. Consequently, in 1988, NIOSH convened a group of hearing conservation experts to consider ways for achieving more effective hearing conservation programs. This guide sets forth the concepts and techniques which this distinguished body of experts has found to be consistent with successful hearing conservation programs. The document is not meant to be a technical treatise, but rather a practical guidebook, which should be useful to those who want to make sure that their hearing conservation programs actually are effective. It is intended for use by employers, middle management personnel, health and safety professionals, union health and safety representatives, noise-exposed employees, and other interested or affected parties concerned with hearing conservation.

NIOSH continues to support engineering controls as the most effective defense against the hazards of noise. We consider them an integral component of any effective hearing conservation program. In many instances, however, the application of engineering controls is not feasible, due to economic or practical considerations. When noise control is not feasible, or until controls can be installed, other aspects of the hearing conservation program must be emphasized. This guide discusses engineering controls only briefly, and concentrates in some detail on those factors which promote effectiveness in the non-engineering aspects of hearing conservation programs. It is our hope that the ideas contained in this guide will promote the actions needed to protect a vital human function - hearing.

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EXECUTIVE SUMMARY

Noise is one of the most pervasive occupational health problems in America today. Approximately nine million workers are exposed on their jobs to noise levels that are potentially hazardous to their hearing. Fortunately, noise-induced hearing loss can be reduced, or often eliminated, through the successful application of occupational hearing conservation programs (HCPs).

A successful HCP benefits both the company and the affected employee. Employees are spared handicapping hearing impairments and evidence suggests that they may experience less fatigue and generally better health. Ultimately, the company benefits from reduced medical expenses and worker compensation costs. In some cases there may be improved morale and work efficiency.

The existence of a HCP (even one that complies with government standards) does not guarantee the prevention of noise-induced hearing loss. Experience with successful HCPs shows that management needs to develop and adhere to certain policies from the start. These policies cover the integration of the HCP into the company's safety and health program, designation of a key individual (a "program implementor") with ultimate responsibility for the overall conduct of the program, standard operating procedures for each phase of the program, the proper identification and use of outside services, and the purchase of appropriate equipment.

This guide, developed by those having long, varied experience in hearing conservation practices, presents some of the important attributes of successful HCPs. Concepts and action items are presented in terms of the responsibilities of three groups of personnel: those representing management, those who implement the HCPs, and the affected or noise-exposed employees. Checklists are provided in the appendices to assist in evaluating HCPs on a step-by-step basis.

The seven basic components of a HCP consist of: (1) noise exposure monitoring, (2) engineering and administrative controls, (3) audiometric evaluation, (4) use of hearing protection devices, (5) education and motivation, (6) record keeping, and (7) program evaluation.

Noise Exposure Monitoring

As with any health hazard, it is important to characterize the hazard accurately and to identify the affected employees. Management should define the specific goals of the sound survey and make sure that operating procedures, as well as resources, are available for collecting and evaluating noise measurements. The results of the noise measurements must be reported to the HCP implementor and to the employees in an understandable format. HCP implementors need to coordinate closely with production employees to make sure that the measurements represent typical production cycles and that noise levels are adequately sampled. Program implementors should see that those who make the measurements closely follow the policies and procedures established by management, that the report explains the results clearly, and that employees are apprised of the results. Employees have the responsibility of sharing their knowledge about the production environment, the machinery, and specific operations with those who measure the noise.

Engineering and Administrative Controls

The use of engineering controls should reduce noise exposure to the point where the hearing hazard is significantly reduced or eliminated. It is especially important for companies to specify low noise levels when purchasing new equipment.

Management needs to identify controllable noise sources, set goals for noise control, and allocate resources to accomplish these goals. Managers should also explore potential administrative controls, such as scheduling that will minimize noise exposure, and quiet and conveniently located lunch and break areas. Program implementors must ensure that communication channels are open between management, noise control personnel, and equipment operators. The equipment operators, in turn, need to communicate their thoughts to management and those in charge of noise control, and must learn to operate and maintain their equipment to take full advantage of the noise controls.

Audiometric Evaluation

Audiometric evaluation is crucial to the success of the HCP, since it is the only way to determine whether noise-induced hearing loss is being prevented by the prescribed hearing conservation actions. Management must allocate sufficient time and resources to the audiometric program to allow accurate testing; otherwise, the resulting audiograms will be useless. Management should also select audiometric technicians and professional consultants with demonstrated competence in relating to employees as well as in performing their duties in the audiometric program. The program implementor must monitor the audiometric program including scheduling, testing, equipment maintenance and calibration, audiogram review, feedback to the employee, and referral. Effective communication and coordination among company personnel, health services, and employees is of utmost importance. Employees need to disclose information about ear problems and prior noise exposures, or problems encountered in taking the audiometric test. They also need to follow up on any recommendations for treatment or further evaluation.

Hearing Protection Devices

In the absence of feasible engineering or administrative controls, hearing protection devices (often referred to as hearing protectors) remain the only means of preventing hazardous noise levels from damaging one's hearing. Unless great care is taken in establishing a hearing protector program, employees will often receive very little benefit from these devices. Each employee can react differently to the use of such devices; and a successful program should respond to individual needs. The primary managerial responsibilities are: to facilitate the procurement of appropriate hearing protection devices, to demonstrate commitment to the program (e.g. by the use of these devices in appropriate situations), to provide the personnel and facilities to train employees in the use and care of hearing protection devices, and to enforce the use of hearing protectors. Program implementors need to be knowledgeable in the details of hearing protector evaluation, selection, and use, and must be able to impart this information to employees. Implementors need to encourage employees to ask questions and to help them solve any problems that may arise. Program implementors also should perform periodic on-site checks of the condition and performance of hearing protectors.

Employees must take responsibility for being fully informed about the need for hearing protection, wearing their hearing protectors correctly at all times, seeking replacements as necessary, encouraging co-workers to use these devices, and communicating problems to their supervisors.

Education and Motivation

Education and motivation sessions are valuable for both management and employees so they will understand that a successful HCP takes commitment, communication, and cooperation. Management should set a high priority on regularly scheduled training sessions, and select articulate, knowledgeable, and enthusiastic instructors. Program implementors, or those who present the sessions, need to make their presentations short, simple, and highly relevant. They need to encourage questions and the expression of concerns, and they must make sure that all problems receive prompt attention. Employees must contribute to their own education by raising questions and concerns, and by informing program implementors when specific procedures are impractical, suggesting alternatives when possible. If HCP personnel fail to provide adequate consideration or follow-up, employees should communicate their concerns to higher levels of management.

Record Keeping

Effective record keeping requires a committed and consistent approach. Each element of the HCP generates its own type of records (e.g., noise survey forms, audiograms, and medical histories) and much of this information needs to be integrated into the employee's health record. Management's responsibility is to provide adequate resources for efficient record processing, review, and storage in addition to training program implementors and procuring outside services if necessary. Management must ensure that confidentiality of personal data is maintained, that HCP records are available to program implementors and government inspectors, and that each employee has access to his or her own files. Program implementors must see that the information entered into the records is accurate, legible, complete, and self-explanatory. They also should ensure that records are standardized, cross-referenced, and properly maintained. Employees should take advantage of the record keeping system by inquiring about their hearing status, especially at the time of the annual audiogram.

Program Evaluation

A thorough evaluation of all the HCP's components is necessary to determine the extent to which the HCP is really working, or if it there are problems, which elements or departments are at fault. There are two basic approaches: (1) to assess the completeness and quality of the program's components, and (2) to evaluate the audiometric data. The first approach may use checklists, such as those found in Appendices A and B, and the second consists of evaluating the results of audiometric tests, both for individuals and for groups of noise-exposed employees. Management should dedicate resources for HCP evaluation (i.e., trained individuals and computer facilities). In addition, managers must be willing to acknowledge and solve problems that arise. If program implementors are not knowledgeable in the mechanics of data base analysis, the company must hire someone with these skills. Program implementors must also be committed to seeking out elusive information, and interacting with all members of the HCP team to identify and correct any deficiencies. As with many other aspects of the HCP, the employee's responsibility with respect to program evaluation is to provide feedback on the program's merits or shortcomings to the program implementor and management.

CONTENTS

INTRODUCTION

Noise is one of the most pervasive problems in today's occupational environment, affecting workers in manufacturing, construction, transportation, agriculture, and the military. Approximately nine million American workers are exposed to noise levels that are potentially hazardous to their hearing. The gradual progression of hearing loss due to noise may be less dramatic than an injury resulting from a workplace accident, but it is a significant and permanent handicap for the affected individual. Loss of hearing denies people sensory experiences that contribute to the quality of their lives. This tragedy is preventable.

Through comprehensive and coordinated efforts on the part of managers, interested employees, and safety and health professionals, much has been learned over the last few decades about implementing hearing conservation programs. A good hearing conservation program (HCP) has at least seven identifiable elements: noise exposure surveys, engineering controls, audiometric evaluations, worker education and training, the use of hearing protection devices, record keeping, and evaluation of overall program effectiveness. The program is usually implemented by a team, whose composition and size tend to be related to the size of the company and the number of noise-exposed employees. Members of the team may include any or all of the following: physician, nurse, audiologist, industrial hygienist, company and/or union safety representative, hearing conservation technician, and acoustical engineer.

This document summarizes the procedures involved in implementing these seven elements. They will be examined from the perspective of management, program implementors, and affected employees; and the responsibilities of each category of participants will be outlined. The management category includes all of those in the position of generating or enforcing policy and authorizing the allocation of resources. Program implementors are those who are charged by management to make the HCP work, and the employees' category includes all persons who are exposed to hazardous levels of occupational noise.

It has become clear over recent years that the level of commitment displayed by management is directly related to the overall effectiveness of the hearing conservation program. A strong commitment to a hearing conservation program can be shown by following these policies:

- Strive for excellence in the program rather than just meeting minimal requirements.
- Integrate the program into the overall company safety and health program..
- Educate and motivate employees, so that hearing conservation practices become an integral part of their behavior on and off the job.
- Designate a key person to serve as implementor/coordinator of the program.
- Strive for simplification and continuity of the program's operating procedures.

o Review the program's effectiveness regularly and make modifications when needed.

The nature and scope of the HCPs recommended in this text go beyond the minimal requirements of federal and state regulations. The objective here is not to reiterate regulatory requirements, although we urge all readers to become thoroughly familiar with the noise standards and regulations for compliance purposes. Instead, the objective is to convey some of the characteristics of good HCPs that are not necessarily found in regulations, and yet which contribute substantially to the program's success. However, to facilitate compliance with Federal regulations for occupational noise exposure, we have included an "OSHA noise standard compliance checklist" as Appendix A, and we have listed the pertinent provisions of the OSHA standard at the end of each section. In addition, for those who wish to pursue certain areas further, we have listed suggested readings at the end of each section, many of which can also be found in the expanded list of suggested readings in Appendix D. The reader's attention should also be directed to: the checklist in Appendix B, which should be helpful in evaluating HCPs that are already in place; Appendix C, which gives a listing of audiovisual materials; and Appendix E, which lists resources in both government and the private sector for those who need further assistance.

As the title states, this is a practical guide, intended to assist employers and those responsible for protecting employees' hearing to develop and maintain hearing conservation programs that actually work, and are not just perfunctory measures. This guide is not meant to be technical in nature. The reader will find no citations to the scientific literature -- only suggested readings at the end of each section. Support for the statements and recommendations made in the text are available in the scientific literature, but we believe that citations are not necessary in a practical guide such as this. The interested reader may pursue these concepts further in the suggested readings.

CENTERS FOR DISEASE CONTROL

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MORBIDITY AND MORTALITY WEEKLY REPORT

Hearing Protectors: Field Measurements

In 1977 and 1981, the National Institute for Occupational Safety and Health (NIOSH) conducted field investigations to determine the amount of noise reduction (attenuation) afforded to industrial workers who use earplugs. Tests of 420 workers at 15 industrial plants indicated that 50% of the workers received less than half the potential protection demonstrated in laboratory testing.

Earplug distributors label their products with noise-reduction indexes based on data from standard audiometric laboratory tests. Although earplugs can provide adequate protection from noise hazards, workers generally wear earplugs incorrectly; thus, distributors' estimates may greatly exceed the actual protection of earplugs.

The field investigations included evaluations of five general types of earplug design: twin-flanged (pre-formed in "small" and "regular" sizes); single-flanged (pre-formed in five sizes); acoustic wool (two types made of user-formed cotton-like material, one with a pre-formed plastic shroud); custom-molded (two types, one vented with a "noise filter"); and expandable acoustic foam (two types differing only in color).

Twenty-eight workers who used the same type of earplug were randomly selected at each plant. The attenuation provided by the earplug was audiometrically measured for each worker and was then plotted against the tested sound frequency (*1,2*). These results were compared with the results of previous laboratory tests of attenuation at the same frequencies, and, in most cases, revealed substantial differences between the attenuation values recorded in the field and those recorded in the laboratory.

The noise reduction afforded each worker was calculated using the attenuation value at each test frequency and a typical industrial noise spectrum adjusted according to a frequency contour (known as "A-weighting") approximating the human ear response (Table 1). Overall, the median reduction value was 13 decibels (dB) under actual working conditions versus 28 dB estimated from data provided by the distributors.

Reported by Div of Biomedical and Behavioral Science, National Institute for Occupation Safety and Health, CDC.

Editorial Note: There are many reasons for differences between the results of field and laboratory testing. Sizing, fit, and method of insertion are usually less than optimal in pre-formed and user-formed earplugs. Effectiveness of the custom-molded types depends on preparation of the impression materials and fit of the final mold. The expandable foam earplugs may not be inserted fully and are often not held in place to prevent slippage as they expand.

Noise-induced hearing loss is one of the most serious and common occupational diseases. More than three million workers wear hearing protectors in industrial environments where adequate engineering controls are unavailable to reduce noise to acceptable limits. The large differences between the laboratory-derived attenuation values provided by distributors and actual attenuation in industrial settings should be considered by employers when choosing earplugs for their employees. Workers can be endangered from excessive noise exposure if employers assume that workers will be protected to the extent indicated by laboratory tests.

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Hearing Protectors — Continued

TABLE 1. Median A-weighted noise reduction

Earplug type	Number of plants	Field tests (dB)*	Laboratory tests† (dB)
Twin-flanged	1	3	30
Single-flanged	3	8	29
Acoustic wool, type A	2	9	22
Acoustic wool, type B	1	11	30
Custom-molded, type A	2	12	20
Custom-molded, type B	2	15	19
Acoustic foam, type A	2	21	36
Acoustic foam, type B	2	17	36

*decibels

†Estimated from data provided by the distributor.

Compendium of Hearing Protection Devices

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Data supplied to NIOSH by manufacturers or distributors of hearing protection devices are presented. These data include: supplier, model, type, weight, headband force, average attenuation values and standard deviations at test frequencies 125 to 8000 Hz, test standard, and test laboratory. Also presented are methods for calculating noise reduction factors for hearing protectors and a discussion of factors to be considered in the selection and use of these devices.

A list of hearing protector data and methods for computing noise reduction was published in September 1975 by the National Institute for Occupational Safety and Health (NIOSH)[1] in response to requests for information regarding the types of hearing protectors available for use in hearing conservation programs. Since that time, a modification (ANSI S3.19-1974)[2] of the standard laboratory method (ANSI Z24.22-1957)[3] for testing hearing protection devices has resulted in the retesting of most products. Also, some companies have left the market, and several new companies have asked that their products be incorporated. For these reasons, a new list has been compiled and is presented in this report.

Data supplied to NIOSH by manufacturers or distributors of hearing protection devices for inclusion in this report are presented in Appendix 1 *as received from the suppliers*. Included in Appendix 1 are: supplier, model, type, weight and headband force in ounces (oz.), average attenuation in decibels (dB) for the test frequencies from 125 to 8000 Hertz (Hz), and standard deviations in dB of these attenuation data. With few exceptions, the hearing protectors listed were tested by Paul L. Michael and Associates, Inc., State College, PA, using the new standard method. In those cases where a different test method or a different laboratory was used, the information is given in the footnotes referenced in the ID number column of Appendix 1.

In the earlier NIOSH report,[1] the majority of suppliers had their hearing protectors tested according to the American National Standards Institute (ANSI) standard Z24.22-1957, "Method for the Measurement of the Real-Ear Attenuation of Ear Protectors at Threshold."[3] Almost all products reported herein have been tested in accordance with the new standard, ASA STD 1-1975 (ANSI S3.19-1974), "Method for the Measurement of Real-Ear Protection of Hearing Protectors and Physical Attenuation of Earmuffs."[2] The main differences between the ASA 1975 standard and the old standard are that the new standard requires use of third-octave bands of noise instead of discrete tones as the test stimuli and it requires a reverberant test room instead of an anechoic test room. Rigorous comparison of attenuation data obtained re Z24.22 presented in the previous (1975) report,[1] with that obtained re S3.19-1974 presented in this report, has not been made. However, in general it appears that data obtained using the new standard show lower mean attenuation values as well as lower standard deviations. Also, attenuation data are presented in this report for "nonlinear" hearing protection devices, whereas such data were not available for inclusion in the previous (1975) report.[1] While standard methods for the real-ear evaluation of nonlinear devices, amplitude sensitive devices, and other hearing protection devices with features designed to operate exclusively against impulse noise are not yet established,[2] there is insufficient data to determine the existence of nonlinearity in continuous noise.

The results from tests using the procedures specified in the above mentioned standards are expressed in terms of the means and standard deviations of the attenuation in dB for each test frequency. These data can be used to make calculations of the noise reduction capabilities of the hearing protectors.

Three methods of making such calculations are presented in this report, along with examples. The attenuation values presented in Appendix 1 were measured under "experimenter (best) fit"[2] conditions in the laboratory. Even under these conditions, there is variation in attenuation from person to person and from test to test. In order to account for this variability, standard deviations can be included in the noise reduction calculations, as has been done in the examples. For each method, the limitations, advantages, and disadvantages are discussed. Except for two changes, these noise reduction computation methods are identical to those presented in the 1975 NIOSH report.[1] The two changes are: 1. the A-weighting* values for octave band sound levels have been reduced by 0.1 dB at 125, 250, and 500 Hz to conform with the weighting values in ANSI S1.4-1971 (R1976) "Specification for Sound Level Meters,"[4] and 2. the C-weighted** value for "pink" noise, or noise that has equal sound pressure levels at all octave bands, used in the second method has been reduced by 0.6 dB (see footnotes on page 29). With these two changes, the noise reduction constant designated R_c in the previous NIOSH report[1] has been converted to the Environmental Protection Agency's Noise Reduction Rating (NRR)[5] to minimize possible confusion.

Considerations in Selection and Use of Hearing Protectors

Calculated noise reduction factors as discussed herein are based on experimenter (best) fit data. To investigate the attenuation achieved in actual use, a field test method was developed by NIOSH and research studies were conducted, using this method.[6-8] The results of these *in-situ* attenuation tests of workers using preformed, acoustic wool, custom-molded, and acoustic foam earplugs, when compared to manufacturer's best-fit laboratory test results, indicated that 50% of the workers tested were receiving less than half the potential attenuation in dBA of the earplugs (determined using experimenter (best) fit mean attenuation values). Approximately 10% of the workers tested received less than 3 dB of protection, regardless of the type of earplug used.

In the area of muff-type protectors, the Mine Safety and Health Administration conducted a study where the noise was recorded simultaneously through microphones placed inside and outside the protective cup as the worker performed his normal work tasks.[9] The results, when compared to manufacturers' best-fit laboratory test results, were similar to those of the NIOSH studies.

*A-weighting is a method of adjusting the noise levels to the response of the human ear.

**C-weighting gives essentially equal weight to the noise levels that can be heard by the human ear.

Mention of commercial names, products, service or data herein, does not represent endorsement by NIOSH.

In order to appropriately estimate the actual noise reduction that will be achieved in actual use, there are several options. Some type of "user-informed fit" could be employed in the standard laboratory method; however, at present there is no concensus as to how to achieve consistency using such a procedure. Field data as those mentioned herein could be used to calculate noise reduction factors; however, substantially more data would need to be collected *and*, if two standard deviations were subtracted from the mean attenuation values in order to estimate the minimum noise reduction that would be achieved by 98% of the population, then the amount of noise reduction would be zero dB in most cases. Lastly, "derating" factors could be used in conjunction with the noise reduction factors presented in Methods 1, 2, and 3; however, more work must be done to arrive at a consistent and meaningful scheme for determining such factors.

Thus, in selecting a hearing protector, calculated noise reduction factors are one important consideration. However, other aspects must be considered which can affect the actual reduction achieved and the acceptance of the device by a worker. The possibility of wearer adjustment should be evaluated in terms of reliability of performance. Additional considerations are durability (shelf life or use life), sanitation-hygienic characteristics, the need of the worker to communicate verbally and to hear warning signals, environmental conditions such as heat, the time needed to install the device, and the amount of time(s) during the day that the device will be worn. If muff type hearing protection devices are used in a position other than "over-the-head" and a retaining strap is available, then it is important to utilize this option which should improve the reliability of the performance of the device. If custom-molded hearing protectors are to be used, the expertise of those persons who will prepare the impression materials and form the final mold should be considered.[8]

In use, factors which usually degrade the noise reduction are: improper fitting at the time of distribution, interference by hair or eyeglasses, and improper wearing by the worker. *Optimum fit of a hearing protector is most important in realizing the expected attenuation because it is on this basis that the attenuation data presented in Appendix 1 were derived.* Less than optimum fit is often a result of attempts to improve comfort and reduce the time needed to install the device. Many companies have found that the practices of personally fitting each worker, offering a variety to types to the workers, and providing regular and frequent monitoring of the proper use and fit of the protectors, have greatly improved acceptance of wearing hearing protectors.

Determination of Noise Reduction for Hearing Protectors

The attenuation data listed in this report show how the effectiveness of each hearing protector depends upon the frequency (Hz) × sound exposure level (dB) content of the assaulting noise. In industrial situations one usually needs to determine the amount by which the total workplace noise, usually expressed in sound levels on an A-scale, is effectively reduced by the hearing protector. Since industrial noise is usually made up of a mixture of individual sounds of various frequencies and strengths, termed its "spectrum," it is necessary to employ some sort of formula in computing the noise reduction to take account of its spectrum. If information regarding the workplace noise spectrum (typically expressed in octave band noise levels) is not available, then safety factors must be included to adjust for this spectral uncertainty. The performance of a hearing protector cannot be predicted exactly because of person to person and test to test variations, and it is appropriate to adjust for these measurement uncertainties as well. The purpose of this section is to provide the reader with the information needed to estimate the effective noise exposure level that may be achieved in a workplace when a hearing protector is worn in *optimum* fashion.

Through a series of calculations a dBA-reduction factor, *R*, is determined. After *R* has been calculated, it can be subtracted from the measured workplace dBA noise level to predict the effective noise exposure level of the worker. For example, if the measured workplace noise is 102 dBA and the *R* factor is 17 decibels, then the worker's effective noise exposure level should be no higher than 85 dBA. However, actual field performance may be substantially poorer than the expected performance if the protector is ill-fitted (see **Considerations in Selection and Use of Hearing Protectors**).

Three methods for calculating reduction factors will be presented with examples to illustrate how they are used. For all three methods, the calculations are similar, using logarithms and antilogarithms which many electronic calculators can compute with the "log x" button for logarithms and with the "10^x" or "y^x" button for antilogarithms. In general, the reduction factor equals the measured workplace noise level minus the effective noise level when wearing the hearing protector. The effective noise level is calculated differently in the three methods, depending upon the workplace noise data available. However, common to the three methods are: 1. the average attenuation at each octave band and a correction for uncertainty in measuring the attenuation; and 2. the dB A-weighting factor for each octave band. When taken together and subtracted from the octave band noise level in dB, these elements reduce the octave band noise level to the effective octave band noise level in dBA. In the equations to follow, these elements have been conveniently combined into a factor, *Q*, for each octave band.

A scheme for computing Q factors, using the data for the first hearing protector listed in Appendix 1 as an example, is presented in Table 1. Note that the average attenuation data for 3150 and 4000 Hz in Appendix 1 are averaged for computing Q factor 6, and similarly the data for 6300 and 8000 Hz have been averaged for computing *Q* factor 7. Twice the standard deviation has been used as the measurement uncertainty correction except for Q factors 6 and 7 where the standard deviations associated with the two frequencies involved have been added. The *Q* factors so calculated are listed in line 1 of Appendix 2, where the *Q* factors for all the hearing protectors listed in Appendix 1 are presented.

The three methods of calculating noise reduction factors differ in the type of noise data used and the resulting accuracy of the estimate. For Method 1, the most accurate method, octave band noise levels, the dBA noise level (which can be computed using the octave band levels), and the *Q* factors are required. For Method 2, the next most accurate method, octave band noise levels are not needed; what is needed is the difference between the dBC and dBA noise levels and the *Q* factors. For Method 3, only Q factors are needed. Method 2 yields a NRR for each hearing protector. The NRR, calculated as shown in the example for Method 2 for each hearing protector, is listed in Appendix 2 along with the Q factors for each hearing protector. It is required under 40 CFR 211.201 that each hearing protector be labeled with a NRR, however, the values listed in Appendix 2 may be different from those used by the manufacturer for a number of reasons: 1. an approximate tabular method for combining the effective (or "protected ear") octave band noise levels may be used instead of the more exacting method of using logarithmic calculations as shown in Method

Table 1. Scheme for calculating Q factors.

Factor Number	Octave Band Center Frequency (Hz)	Average Attenuation (dB) A	A-weighting Factor (dB) B	Measurement Uncertainty (dB) C	Q Factor (dB) A+B–C
1	125	21	16.1	(2)(2.4)	32.3
2	250	22	8.6	(2)(2.0)	26.6
3	500	24	3.2	(2)(2.1)	23.0
4	1000	30	0	(2)(2.4)	25.2
5	2000	36	−1.2	(2)(2.5)	29.8
6	4000	(41 + 39)/2	−1.0	3.4 + 4.8	30.8
7	8000	(37 + 35)/2	1.1	2.5 + 2.7	31.9

2; 2. mean attenuation values for each product shown in this report are rounded to the nearest integer (values of 0.5 have been rounded down) and these rounded values were used to compute the NRR value shown in Appendix 2; 3. the manufacturer may label the protector at values different than indicated by the test results and by the computation procedure presented in this report; and 4. changes in the manufacturer's product and variability between different laboratory tests of the product.

The three computational methods usually yield different R factors for a given hearing protector/noise combination. The less precise methods are principally based on assumptions concerning *possible* noise spectra encountered in industry. These less precise methods include adjustments to guard against overestimating the R factor or underestimating the expected noise exposure when the hearing protector is used. As a general rule: the greater the accuracy of a method, the greater the computed value of R. Another consideration which affects the value of R in all methods is the adjustment factor to account for statistical variations from person to person. The adjustment procedure which has been used throughout this report is to reduce the listed attenuation values by subtracting twice the standard deviation values (or the equivalent when combining data; see Table 1) obtained in the laboratory measurements. This procedure should assure that most wearers will obtain the expected benefits from the hearing protector most of the time, when it is worn under the test conditions of optimum fit. If the standard deviations for a particular hearing protector are not available, then it may be suitable to use the worst-case data listed in Appendix 1 for other protectors of similar design. Alternatively, the reader may choose some adjustment for measurement uncertainty other than twice the listed standard deviation. (See **Considerations in Selection and Use of Hearing Protectors.**)

A guide for choosing a method for calculating noise reduction factors is presented in Table 2, and the detailed presentations and discussion of each method follow.

Table 2. Guide to choosing a method for computing noise reduction.

Method 1 (Most Accurate Method: Recommended)	
Data required	Octave band noise levels at 125, 250, 500, 1000, 2000, 4000 and 8000 Hz, denoted by L_1, L_2, L_3, L_4, L_5, L_6, and L_7, respectively.
	The dBA noise level (which can be computed using the octave band noise levels).
	Q factors.
Comments	Most precise of the three methods.
	Does not require an adjustment for spectral uncertainty.
	Computed R factor is appropriate only for a given noise spectrum, but the same R can be used for different dBA levels if only the intensity of the given noise changes.
	R factor is subtracted from the workplace dBA level to give the effective dBA level when the hearing protector is worn.
Method 2	
Data required	The difference (δ) between the dBC and dBA levels is needed to compute R, but not for the modified R described below. δ (delta) = $L_C - L_A$.
	Q factors.
Comments	Second-most precise of the three methods.
	Incorporates an adjustment of minus 3 dB to account for spectral uncertainty.
	The effective dBA level can be computed by using R or a modified R factor called "NRR." NRR is subtracted from the workplace dBC level, whereas R is subtacted from the dBA level.
	NRR is a constant, however, R will change for each situation in which the δ is not the same.
Method 3 (Least Accurate)	
Data required	Q factors.
Comments	Least precise of the three methods.
	Incorporates an adjustment of minus 8.5 dB to account for spectral uncertainty (A less constraining procedure may be used if a certain assumption can be made - see "Discussion" for Method 3.).
	R factor can be computed without noise level data.
	R factor is subtracted from workplace dBA level to give the effective dBA level.

Method 1: Detailed Presentation and Discussion

Formula

$$R = L_A - 10 \log S$$

where R = dBA-reduction factor

L_A = workplace dBA noise level

$$S = \text{antilog}\,[(0.1)(L_1 - Q_1)] + \text{antilog}\,[(0.1)(L_2 - Q_2)] + \text{antilog}\,[(0.1)(L_3 - Q_3)] + \text{antilog}\,[(0.1)(L_4 - Q_4)] + \text{antilog}\,[(0.1)(L_5 - Q_5)] + \text{antilog}\,[(0.1)(L_6 - Q_6)] + \text{antilog}\,[(0.1)(L_7 - Q_7)]$$

L_1, L_2, L_3, L_4, L_5, L_6, and L_7, denote octave band sound levels at 125, 250, 500, 1000, 2000, 4000, and 8000 Hz, respectively

Q_1, Q_2, Q_3, Q_4, Q_5, Q_6, and Q_7, account for the attenuation of a given hearing protector (method for computation shown in Table 1)

Q factors for hearing protectors in Appendix 1 are in Appendix 2.

antilog $(x) = 10^x$

Example

Suppose a hearing protector is needed in an area with a noise level of 95 dBA and octave band noise levels of:

125	250	500	1000	2000	4000	8000 Hz
88	89	85	89	89	89	80 dB

and a fictitious hearing protector with the following mean attenuation and (standard deviation) characteristics is used:

125	250	500	1000	2000	3150	4000	6300	8000 Hz
21	22	23	29	41	47	43	40	37 dB
(3.7)	(3.3)	(3.8)	(4.7)	(3.3)	(4.0)	(2.7)	(6.0)	(6.6) dB

The "Q" (see Table 1 and Appendix 2) and "$L - Q$" values in S are:

$Q_1 = 21 + 16.1 - (2)(3.7) = 29.7$ $\quad (L_1 - Q_1) = 88 - 29.7 = 58.3$

$Q_2 = 22 + 8.6 - (2)(3.3) = 24.0$ $\quad (L_2 - Q_2) = 89 - 24.0 = 65.0$

$Q_3 = 23 + 3.2 - (2)(3.8) = 18.6$ $\quad (L_3 - Q_3) = 85 - 18.6 = 66.4$

$Q_4 = 29 + 0 - (2)(4.7) = 19.6$ $\quad (L_4 - Q_4) = 89 - 19.6 = 69.4$

$Q_5 = 41 - 1.2 - (2)(3.3) = 33.2$ $\quad (L_5 - Q_5) = 89 - 33.2 = 55.8$

$Q_6 = (47 + 43)/2 - 1.0 - 4.0 - 2.7 = 37.3$

$(L_6 - Q_6) = 89 - 37.3 = 51.7$

$Q_7 = (40 + 37)/2 + 1.1 - 6.0 - 6.6 = 27.0$

$(L_7 - Q_7) = 80 - 27.0 = 53.0$

Applying the formula for the dBA reduction factor,

$$R = L_A - 10 \log S$$

where $L_A = 95$

and S = antilog [(0.1)(58.3)] + antilog [(0.1)(65.0)] + antilog [(0.1)(66.4)] + antilog [(0.1)(69.4)] + antilog [(0.1)(55.8)] + antilog [(0.1)(51.7)] + antilog [(0.1)(53.0)]

= 676,083 + 3,162,278 + 4,365,158 + 8,709,636 + 380,189 + 147,911 + 199,526

= 17,640,781

$$R = 95 - 10 \log (17{,}640{,}781) = 95 - 72.5 = \mathbf{22.5\ dB}$$

The effective dBA level is

$$L_A - R = 95 - 22.5 = 72.5 \text{ dBA},$$

which, incidentally, is equal to the value of the term "10 log S." Alternatively, the effective dBA level can be estimated using the "$L - Q$" values and Table 3, as shown in Table 4. Use of Table 3 to determine the effective dBA level can result in an overestimate of the R factor of 0.3 dB.

Discussion

The R factor calculated by this method only has an adjustment to account for measurement uncertainty which is accomplished by subtracting twice the standard deviation values from the corresponding attenuation values. No adjustment for spectral uncertainty is needed because the attenuation data are subtracted directly from the octave band levels of the noise. This is the most precise method and may be used as an ideal reference against which other methods can be compared.

This method has the drawback that a different R has to be calculated for each noise spectrum, but the same R can be used for different dBA levels if only the level of the given noise changes.

The use of this method is strongly recommended when speech communication or the ability to hear other environmental information is an important concern.

Method 2: Detailed Presentation and Discussion

Formula

$$R = \text{NRR} - \delta = (4.9 - 10 \log T) - \delta$$

where R = dBA-reduction factor

NRR = 4.9 - 10 log T (see Discussion)

T = antilog $[(-0.1)(Q_1)]$ + antilog $[(-0.1)(Q_2)]$ + antilog $[(-0.1)(Q_3)]$ + antilog $[(-0.1)(Q_4)]$ + antilog $[(-0.1)(Q_5)]$ + antilog $[(-0.1)(Q_6)]$ + antilog $[(-0.1)(Q_7)]$

$\delta = L_C - L_A$

L_C = workplace dBC noise level

L_A = workplace dBA noise level

$Q_1, Q_2, Q_3, Q_4, Q_5, Q_6$, and Q_7, account for the attenuation of a given hearing protector (method for computation shown in Table 1)

NRR values are given in Appendix 2 for hearing protectors in this list.

The expression antilog $[(-0.1)(Q)]$ is equivalent to antilog $[(0.1)\cdot(L - Q)]$, where $L = 0$.

antilog $(x) = 10^x$

Example

Suppose a fictitious hearing protector with the following mean attenuation and (standard deviation) characteristics is used:

125	250	500	1000	2000	3150	4000	6300	8000 Hz
21	22	23	29	41	47	43	40	37 dB
(3.7)	(3.3)	(3.8)	(4.7)	(3.3)	(4.0)	(2.7)	(6.0)	(6.6) dB

If this hearing protector were actually in the list, NRR could be found by using the protector's I.D. No. to locate the value in Appendix 2. In this case, however, the "10 log T" value must be computed as shown below and is equal to -14.9. Workplace noise levels are: $L_C = 96$, $L_A = 95$. Applying the formula,

$$R = \text{NRR} - \delta$$

where NRR = 4.9 − 10 log T = 4.9 − (−14.9) = 19.8 dB

$\delta = 96 - 95 = 1$

$$R = 19.8 - 1 = \mathbf{18.8\ dB}$$

The effective dBA level is

$$L_A - R = 95 - 18.8 = 76.2 \text{ dBA}$$

or, using NRR and the dBC noise level, the effective dBA level is

$$L_C - \text{NRR} = 96 - 19.8 = 76.2 \text{ dBA}$$

Computation of 10 log T

The "Q" values in are:

$Q_1 = 21 + 16.1 - (2)(3.7) = 29.7$

$Q_2 = 22 + 8.6 - (2)(3.3) = 24.0$

$Q_3 = 23 + 3.2 - (2)(3.8) = 18.6$

$Q_4 = 29 + 0 - (2)(4.7) = 19.6$

$Q_5 = 41 - 1.2 - (2)(3.3) = 33.2$

$Q_6 = (47 + 43)/2 - 1.0 - 4.0 - 2.7 = 37.3$

$Q_7 = (40 + 37)/2 + 1.1 - 6.0 - 6.6 = 27.0$

and T = antilog $[(-0.1)(29.7)]$ + antilog $[(-0.1)(24.0)]$ + antilog $[(-0.1)(18.6)]$ + antilog $[(-0.1)(19.6)]$ + antilog $[(-0.1)(33.2)]$ + antilog $[(-0.1)(37.3)]$ + antilog $[(-0.1)(27.0)]$

= 0.00107 + 0.00398 + 0.01380 + .01096 + 0.00048 + 0.00019 + 0.00200

= 0.03248

$$10 \log T = 10 \log (0.03248) = (10)(-1.49) = -14.9$$

Discussion

This method is based upon a simplifying assumption which is applied to a procedure developed by J. Botsford.[10] A "sound level conversion" value, or a modified R factor (denoted herein as NRR), is computed by using the attenuation data of a hearing protector and a single noise spectrum which is composed of equal sound pressure levels for all octave bands ("pink" noise). [This noise spectrum represents the median "shape," with δ equal to approximately 1.5, of the sample of 100 noise spectra shown in Figure 1 of the previous (1975) report,[1] which were chosen to correspond to the distribution of noise exposures found in major industries in the U.S.] The computation of NRR involves subtracting the effective dBA level from the dBC level of the assumed pink noise. The result of this subtraction can be shown to equal "7.9 − 10 log T.", where T is derived from the hearing protector attenuation data including adjustments for measurement uncertainty.* However, an additional adjustment** of 3 dB is then required to protect against overestima-

Table 3. Values used for summing two decibel (dB) levels.

Higher Minus Lower Level	Add to Higher Level	Higher Minus Lower Level	Add to Higher Level
0.0 to 0.1	3.0	3.7 to 4.0	1.5
0.2 to 0.3	2.9	4.1 to 4.3	1.4
0.4 to 0.5	2.8	4.4 to 4.7	1.3
0.6 to 0.7	2.7	4.8 to 5.1	1.2
0.8 to 0.9	2.6	5.2 to 5.6	1.1
1.0 to 1.2	2.5	5.7 to 6.1	1.0
1.3 to 1.4	2.4	6.2 to 6.6	0.9
1.5 to 1.6	2.3	6.7 to 7.2	0.8
1.7 to 1.9	2.2	7.3 to 7.9	0.7
2.0 to 2.1	2.1	8.0 to 8.6	0.6
2.2 to 2.4	2.0	8.7 to 9.6	0.5
2.5 to 2.7	1.9	9.7 to 10.7	0.4
2.8 to 3.0	1.8	10.8 to 12.2	0.3
3.1 to 3.3	1.7	12.3 to 14.5	0.2
3.4 to 3.6	1.6	14.6 to 19.3	0.1
		= or > 19.4	0.0

Table 4. Example for using Table 3 to sum seven octave band levels in Method 1 example (seven octave band levels shown are seven "L − Q" values).

Octave Band Level	Previous Result	Higher Minus Lower Level	Add to Higher Level		Higher Level		Result
58.3	-	-	-		-		58.3
65.0	58.3	6.7	0.8	+	65.0	=	65.8
66.4	65.8	0.6	2.7	+	66.4	=	69.1
69.4	69.1	0.3	2.9	+	69.4	=	72.3
55.8	72.3	16.5	0.1	+	72.3	=	72.4
51.7	72.4	20.7	0.0	+	72.4	=	72.4
53.0	72.4	19.4	0.0	+	72.4	=	72.4

*The value 7.9 dB corresponds to the dBC level for pink noise used in the EPA Noise Reduction Rating (NRR) which was computed over the octave bands 125 to 8000 Hz. In the previous NIOSH (1975) report,[1] dBC levels were computed over the 63 to 8000 Hz octave bands (for all noise spectra used in the determination of correction factors for spectral uncertainty; see footnote below) and the pink noise value was 8.5 dB.

**This adjustment factor is the 98th percentile point in the error distribution of values of R computed using δ as an index of the noise spectrum versus values of R computed using octave band sound pressure levels. This factor was determined using the attenuation data and the 100 noise spectra presented in the previous (1975) report[1] and a pink noise dBC level of 8.5 dB. If the pink noise value of 7.9 dB had been included in the determination of the 98th percentile adjustment factor, then this factor would have been 2.4 dB instead of 3 dB. Thus, an additional adjustment factor of 0.6 dB has been included.

tion because of the possible variations in the spectra of actual workplace noises. The dBA reduction factor, R, is then just NRR minus δ. Thus, the expression for R is:

$$R = 7.9 - 10 \log T - \delta - 3 = 4.9 - 10 \log T - \delta = \text{NRR} - \delta$$

As shown in the example for this method, the effective dBA level can be computed using NRR as well as R. The only difference is that NRR is subtracted from the dBC level whereas R is subtracted from the dBA level. Being a constant for a given hearing protector, NRR is convenient to use if the workplace dBC noise level is known; furthermore, it makes determination of δ unnecessary. R, however, is dependent on the value of δ (i.e. $L_C - L_A$) for the workplace noise and is not necessarily constant for a given hearing protector.

Since a variable R factor could cause some difficulty in its use, a conservative procedure can be used to calculate a constant value of R if one has sufficient knowledge of the δ values of noise in the workplace. The procedure is to determine the highest value of δ at the workers' positions of concern and use that value in the equation for R. The resulting R factor can be subtracted from dBA levels throughout the workplace to determine the effective dBA noise levels. As an example, if one were sure that the value of δ were no greater than 5.0 at all locations in his factory, then a single R factor of 14.8 dB could be used for the hearing protector of the above example ($R = \text{NRR} - \delta = 19.8 - 5.0$).

Method 3: Detailed Presentation and Discussion

Formula

$$R = -1.5 - 10 \log T \cong \text{NRR} - 7$$

where R = dBA reduction factor

NRR = 4.9 − 10 log T (see discussion of NRR under Method 2)

T = antilog $[(-0.1)(Q_1)]$ + antilog $[(-0.1)(Q_2)]$ + antilog $[(-0.1)(Q_3)]$ + antilog $[(-0.1)(Q_4)]$ + antilog $[(-0.1)(Q_5)]$ + antilog $[(-0.1)(Q_6)]$ + antilog $[(-0.1)(Q_7)]$

Q_1, Q_2, Q_3, Q_4, Q_5, Q_6, and Q_7, account for the attenuation of a given hearing protector (method for computation shown in Table 1)

antilog $(x) = 10^x$

Example

As an example, the fictitious hearing protector used under Method 2, with a "10 log T" value of −14.9, is used below. Applying the formula,

$$R = -1.5 - 10 \log T = -1.5 - (-14.9) = \mathbf{13.4\ dB}$$

For a workplace dBA level of 95, the effective dBA level is $L_A - R = 95 - 13.4 = 81.6$ dBA

Discussion

This method requires no noise measurements to compute R. The formula has been derived by assuming a noise spectrum which is composed of equal sound pressure levels for all octave bands ("pink" noise). [This noise spectrum represents the median "shape" of the sample of 100 noise spectra shown in Figure 1 of the previous (1975) report,[1] which were chosen to correspond to the distribution of noise exposures found in major industries in the U.S.] The computation of R involves subtracting the effective dBA level from the dBA level of the assumed pink noise. The result of this subtraction can be shown to equal "7.0 − 10 log T", where T is derived from the hearing protector attenuation data including adjustments for measurement uncertainty. However, an additional adjustment* of 8.5 dB is then required to protect against overestimation of R because of variation in the noise spectra of actual industrial noises. The resulting expression for R is:

$$R = 7.0 - 10 \log T - 8.5 = -1.5 - 10 \log T$$

Once the value of "10 log T" is determined, R is computed by a single subtraction. A possible disadvantage with this method is that too low of a value of R might result because of the necessity for having a large adjustment factor (8.5 dB). To demonstrate differences that can occur between the methods, the R factors in the examples for Methods 1, 2, and 3 were computed using the same hearing protector and the same noise data. The results are: Method 1 (22.5 dB), Method 2 (18.8 dB), and Method 3 (13.4 dB). If an unsatisfactory R is computed using Method 3, several alternatives are available to the user. Possibly a different hearing protector with a larger R factor could be selected, or additional noise data (octave band sound levels or dBC levels) can be obtained in order to use Method 1 or Method 2, which will usually yield greater values of R. However, given the likelihood that the true noise reduction factor is typically at least 6 dB higher (possibly as much as 12 dB higher depending on the actual noise spectrum), use of dBC levels or octave band levels is strongly recommended when speech communication or other environmental information is an important concern.

Even if the noise data needed to compute R by Method 2 is not directly available, the Method may still be used if a certain assumption can be made about the term δ (delta), which is the difference between the dBC (L_C) and dBA (L_A) levels of the workplace noise ($\delta = L_C - L_A$). The procedure is to assume the highest value of δ expected for actual noises within a given workplace and use that value in the formula for R presented in Method 2 (i.e. $R = 4.9 - 10 \log T - \delta$). The assumed value of δ should be based on actual noise measurements, noise data from a similar operation, or some other well-founded reason.

The formula for R in Method 3 can be rearranged to illustrate how it is similar to the Method 2 formula:

$$R = -1.5 - 10 \log T = 4.9 - 10 \log T - 6.4 \cong \text{NRR} - 7$$

In this form, the Method 3 formula is shown to be equal to the Method 2 formula for a δ value of approximately 7.** This point is important because a certain amount of caution should be exercised in using Method 3 in workplaces where dBC − dBA ($L_C - L_A$) differences might be greater than 7. This situation is relatively easy to recognize because it implies dominant low frequency noise, with a substantial rumble or roar. This slight restriction in the application of the formula emerged out of the development of the method. Method 3 was designed to meet the requirement of: 1. having a simple, short procedure for calculating R without knowing any noise levels; 2. obtaining a constant R factor (for a given hearing protector) which can be subtracted from measured dBA levels to give the effective dBA level; and 3. having a value of R which is not unreasonably small for most protectors. Without the indicated restriction, an adjustment factor larger than 8.5 dB would be needed which could result in values of R being almost too low to be useful. Therefore, use caution in applying a Method 3 R factor if low frequency noises are present, and when in doubt, use Method 1 or 2, if possible.

*This adjustment factor is the 98th percentile point in the error distribution of values of R computed by the Method 3 procedure versus values of R computed using octave band sound pressure levels. This factor was determined using the attenuation data and the 100 noise spectra presented in the previous (1975) report.[1]

**Although the formula $R = \text{NRR} - 6.4$ is consistent with the correction factor of 8.5 dB for spectral uncertainty, the "approximate" formula $R \cong \text{NRR} - 7$ is presented to avoid undue confusion with applications of Method 3 as presented in the previous (1975) report.[1]

References

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Appendix I. List of Hearing Protection Devices and Attenuation Data as Supplied by the Manufacturers and Distributors

Legend for Design Codes 1, 2, and 3

Design Code 1 (Type)

Code	Description
PN	Plugs Pre-Molded, No Flanges
P1	Plugs Pre-Molded, One Flange
P2	Plugs Pre-Molded, Two Flanges
P3	Plugs Pre-Molded, Three Flanges
P5	Plugs Pre-Molded, Five Flanges
PC	Plugs Pre-Molded, Conical
PU	Plugs User-Molded
PS	Plugs Special (Custom)-Molded
PE	Plugs Self-Molding (Expandable)
CS	Plugs Pre-Molded, Concha Seated
MO	Muffs Over-the-Head
MB	Muffs Behind-the-Head
MU	Muffs Under-the-Chin
MH	Muffs Mounted On Helmet

Design Code 2 (Materials)

Code	Description
AC	Acrylic Plug
FO	Foam Plug
GF	Glass Fiber Plug
SI	Silicone Plug
VI	Vinyl Plug
WC	Wax-Cotton Plug
LM	Liquid-Filled Muff Cushion With Metal Headband
LP	Liquid-Filled Muff Cushion With Plastic Headband
FM	Foam-Filled Muff Cushion With Metal Headband
FP	Foam-Filled Muff Cushion With Plastic Headband
FH	Foam-Filled Muff Cushion Mounted on Helmet

Design Code 3 (If Applicable)

Code	Description
B	Plugs With Headband
C	Safety Cord (Option)
D	Disposable Plug Type
R	Muffs With Retaining Strap
A	Active Headset (Option)

"I.D. No." Footnotes
a Tested re ANSI Z24.22-1957
b Tested re ANSI-1969 at the Audiology Center of Redlands, Redlands, CA.
c Tested by Industrial Acoustics Company, Bronx, NY.
d Tested by Audiology Centers of Los Angeles, Los Angeles, CA.

I.D. No.	Manufacturer or Supplier	Model	Design Code 1	2	3	Weight (Force) oz.	Average Attenuation in dB vs. Frequency in Hz (Standard Deviation in dB) 125	250	500	1000	2000	3150	4000	6300	8000
1	Adco Hearing Conservation 1558 California Street Denver, CO 80202 (303) 893-0624	Adcosil Custom	PS	SI	C		21 (2.4)	22 (2.0)	24 (2.1)	30 (2.4)	36 (2.5)	41 (3.4)	39 (4.8)	37 (2.5)	35 (2.7)
2	Airco Inc/Jackson Products 5801 Safety Drive N.E.	EP-1,2,3 EP-1C,2C,3C	P3	SI	D C		22 (2.6)	24 (2.0)	29 (3.1)	33 (2.3)	36 (2.3)	38 (2.4)	41 (1.4)	40 (2.8)	39 (3.0)
3	Belmont, MI 49306 (616) 784-6200	SA-30	MO	FM	R	9 (17)	15 (3.2)	21 (3.0)	26 (3.8)	33 (3.1)	33 (3.2)	32 (3.8)	31 (3.5)	35 (5.0)	37 (4.0)
4		SA-30MB	MH	FP		9	14 (2.3)	18 (2.4)	27 (2.8)	32 (2.1)	36 (2.4)	39 (2.1)	41 (2.6)	40 (3.1)	37 (3.0)
5		SA-20	MB	FM	R	6 (21)	8 (2.4)	14 (2.2)	19 (2.4)	26 (1.7)	34 (1.8)	38 (3.4)	37 (3.8)	33 (3.6)	31 (3.0)
6		SA-10	P1	AC	B		10 (2.0)	15 (2.0)	17 (1.8)	20 (1.9)	31 (2.8)	34 (2.1)	31 (2.0)	31 (1.9)	31 (3.4)
7	American Allsafe Co. 99 Wales Avenue	HS-2326	MO	FM		9 (30)	20 (3.1)	23 (2.7)	29 (2.6)	39 (2.1)	38 (2.5)	38 (3.4)	39 (2.6)	43 (2.5)	42 (2.8)
8	Tonawanda, NY 14151 (716) 695-8300	HS-2336	MB	FM		9 (30)	20 (5.7)	22 (4.1)	29 (3.6)	39 (3.7)	39 (3.1)	38 (3.2)	39 (3.5)	41 (3.1)	40 (4.6)
9		HS-2326	MU	FM		9 (30)	18 (3.8)	22 (3.4)	29 (3.7)	36 (3.3)	40 (2.4)	38 (2.8)	39 (3.4)	40 (2.8)	41 (3.7)
10		HS-260 on Cam-Hi Helmet w/Capmate	MH	FH		8	20 (2.9)	24 (2.1)	29 (3.5)	35 (1.7)	37 (2.2)	40 (1.8)	42 (2.0)	41 (2.7)	41 (2.3)
11		HS-2023	MO	FM		6 (27)	13 (2.1)	20 (2.0)	23 (2.0)	33 (3.0)	37 (3.2)	42 (3.0)	40 (2.0)	40 (3.0)	37 (4.0)
12		HS-2023	MB	FM		6 (27)	13 (3.6)	18 (2.7)	21 (2.4)	31 (3.6)	33 (3.2)	41 (1.7)	39 (2.5)	38 (3.5)	35 (4.1)
13		HS-2023	MU	FM		6 (27)	14 (2.9)	19 (2.3)	22 (2.2)	34 (2.1)	34 (3.3)	41 (2.4)	40 (3.0)	38 (3.3)	35 (3.5)
14		HS-220 on Bullard Helmet w/Capmate	MH	FH		7	15 (2.0)	18 (2.5)	23 (2.0)	32 (2.0)	35 (2.3)	42 (1.5)	42 (2.2)	42 (3.3)	40 (3.6)
15		HS-1820	MO	FP		5 (30)	13 (2.1)	15 (2.7)	20 (1.7)	32 (2.0)	34 (2.2)	40 (2.6)	40 (2.1)	40 (3.0)	39 (3.3)
16		HS-1820	MB	FP		5 (30)	12 (2.6)	15 (2.1)	20 (1.9)	32 (2.0)	33 (2.9)	41 (2.8)	41 (1.9)	40 (3.5)	38 (3.4)

I.D. No.	Manufacturer or Supplier	Model	Design Code 1	Design Code 2	Design Code 3	Weight (Force) oz.	125	250	500	1000	2000	3150	4000	6300	8000
							Average Attenuation in dB vs. Frequency in Hz (Standard Deviation in dB)								
17		HS-1820	MU	FP		5 (30)	11 (2.7)	15 (3.2)	19 (1.9)	30 (3.4)	31 (3.0)	38 (2.9)	38 (2.4)	37 (3.0)	36 (3.4)
18		HS-216 on Cam-Hi Helmet w/Capmate	MH	FH		7	18 (2.8)	18 (2.0)	22 (2.1)	31 (3.0)	32 (2.4)	40 (3.2)	42 (2.3)	42 (2.3)	41 (3.0)
19		A-220	CS		B		10 (2.0)	15 (2.0)	17 (1.8)	20 (1.9)	31 (2.8)	34 (2.1)	31 (2.0)	31 (1.9)	31 (3.4)
20		A-FM & 26	P3	SI	C		25 (6.1)	26 (5.7)	24 (5.2)	26 (2.8)	32 (3.9)	38 (6.7)	42 (7.1)	43 (8.5)	46 (8.6)
21	American Optical Corp. 14 Mechanic Street	1720	MO	FM		8	15 (1.8)	20 (1.7)	27 (2.1)	33 (2.4)	35 (1.6)	37 (2.0)	39 (2.0)	40 (1.8)	38 (2.3)
22	Southbridge, MA 01550 (617) 765-9711	1720	MB	FM		8	7 (1.9)	15 (2.2)	22 (3.5)	28 (3.0)	35 (2.0)	35 (1.9)	36 (2.2)	36 (2.1)	35 (1.9)
23		1720	MB	FM	R	8	10 (2.8)	15 (1.8)	24 (2.7)	32 (2.3)	35 (1.9)	37 (1.7)	37 (1.9)	37 (2.5)	35 (2.2)
24		1720	MU	FM		8	6 (1.8)	13 (2.3)	21 (3.7)	27 (3.0)	32 (2.2)	32 (2.5)	35 (2.1)	35 (1.7)	34 (1.6)
25		1776K	MH	FM		7	14 (3.0)	17 (3.5)	27 (3.2)	35 (2.3)	39 (2.0)	38 (2.1)	36 (2.5)	35 (1.8)	34 (2.5)
26		AO Sound Out Over-the-Head	CS		B	2	16 (2.4)	17 (2.8)	20 (3.2)	26 (3.2)	31 (2.7)	34 (1.6)	32 (1.9)	29 (2.7)	30 (3.7)
27		AO Sound Out Under-the-Chin	CS		B	2	21 (3.1)	19 (2.8)	18 (2.8)	23 (1.9)	29 (2.3)	32 (2.3)	29 (1.9)	27 (1.9)	27 (2.9)
28		AO Sound Out Behind-the-Head	CS		B	2	20 (2.7)	19 (2.1)	18 (2.6)	23 (2.0)	29 (2.9)	33 (2.5)	31 (3.2)	29 (2.5)	27 (3.5)
29		AO Quiet Tip	PC	VI			27 (3.4)	27 (3.4)	28 (4.4)	32 (3.4)	37 (2.8)	42 (3.4)	38 (4.6)	36 (3.4)	34 (3.6)
30		V51R	P1	VI	C		20 (2.2)	23 (2.2)	25 (2.3)	29 (1.8)	35 (2.0)	38 (2.5)	39 (2.3)	38 (3.3)	39 (2.8)
31b	Aural Research 190 West Santa Fe Street Pomona, CA 91767 (714) 596-6112	AR-200-P	MO	FM	R	11 (32)			11 (5.4)	4 (4.2)	8 (6.5)	8 (4.9)	8 (6.2)	17 (9.7)	
32	Aural Technology Inc. 12722 Riverside Drive	Protectear (Vented Pos.)	PS	VI	C		7 (3.8)	8 (3.9)	13 (2.2)	20 (2.6)	29 (3.0)	36 (2.6)	36 (2.6)	31 (3.0)	27 (3.5)
33	North Hollywood, CA 91607 (213) 760-2020	Protectear (Occluded)	PS	VI	C A		29 (5.0)	29 (4.9)	31 (4.2)	35 (5.3)	37 (2.4)	43 (2.6)	41 (3.7)	39 (4.8)	39 (4.2)
34	Bilsom International Inc. 11800 Sunrise Valley Drive	Propp-O-Plast 5521 & 5026	PE	GF	D		23 (3.6)	24 (2.8)	26 (2.5)	26 (3.0)	34 (3.0)	39 (2.2)	40 (2.8)	41 (3.2)	38 (3.6)
35	Reston, VA 22091 (703) 620-3950	Soft 5031	PE	GF	D		27 (3.3)	28 (3.2)	29 (3.1)	32 (2.4)	37 (2.8)	44 (2.1)	43 (2.3)	43 (3.9)	43 (2.7)
36		Eardown 2000 & 3001	PU	GF	D		10 (2.4)	13 (1.6)	16 (1.9)	20 (1.9)	31 (1.9)	36 (1.6)	37 (2.4)	36 (2.1)	34 (1.4)
37		Per-Fit 5601, 5602 5603, 5604	PC	SI	C		29 (3.7)	29 (3.8)	30 (3.2)	32 (2.1)	37 (2.5)	43 (3.0)	40 (5.1)	39 (4.6)	35 (3.1)
38		Universal Muff 2308 (UF-1)	MO	FP		6 (24)	17 (1.9)	20 (1.3)	26 (2.4)	33 (1.7)	40 (1.5)	45 (1.9)	47 (1.4)	45 (1.9)	44 (2.8)
39		Universal Muff 2308 (UF-1)	MU	FP		6 (24)	13 (1.9)	17 (1.1)	24 (1.7)	32 (2.2)	39 (1.5)	42 (1.7)	43 (1.5)	41 (1.9)	38 (1.9)
40		Universal Muff 2308 (UF-1)	MB	FP		6 (24)	14 (2.0)	19 (1.8)	26 (2.4)	33 (2.1)	40 (1.2)	44 (1.1)	46 (2.0)	43 (2.2)	41 (2.8)
41		Viking Muff 2318 SDF-1	MO	FP	R	9 (52)	23 (2.2)	25 (2.0)	31 (1.9)	36 (2.2)	40 (2.0)	42 (2.3)	41 (3.2)	39 (3.2)	37 (3.0)
42		Viking Muff 2318 SDF-1	MB	FP	R	9 (46)	21 (1.8)	24 (1.8)	31 (2.6)	36 (1.7)	39 (2.6)	41 (3.6)	42 (2.7)	39 (2.5)	36 (1.9)
43		Viking Muff 2318 SDF-1	MU	FP	R	9 (46)	21 (3.1)	24 (1.9)	31 (1.7)	35 (1.4)	37 (2.0)	40 (2.1)	41 (2.3)	39 (2.5)	35 (2.3)
44		Bilsom Comfort 2315 MDF1	MO	FP	R	8 (46)	17 (2.1)	21 (1.9)	24 (2.0)	36 (1.8)	38 (1.8)	41 (2.4)	42 (1.6)	39 (2.5)	36 (1.9)
45		Bilsom Comfort 2315 MDF1	MB	FP	R	8 (38)	16 (2.1)	19 (2.4)	24 (1.9)	33 (1.7)	38 (1.9)	41 (2.6)	42 (2.4)	40 (2.9)	37 (2.6)
46		Bilsom Comfort 2315 MDF1	MU	FP	R	8 (38)	14 (1.9)	17 (1.7)	24 (1.9)	34 (1.8)	37 (1.7)	40 (2.8)	40 (2.6)	37 (2.8)	35 (1.7)
47		Bilsom Comfort 2315 MHF-20	MH	FP		9 (25)	14 (2.8)	18 (2.0)	25 (2.5)	34 (2.5)	35 (3.0)	40 (2.5)	41 (2.2)	41 (2.7)	38 (2.8)
48		Viking 2314 SHF-30	MH	FP		10 (34)	15 (1.8)	21 (2.0)	27 (2.5)	37 (2.8)	36 (1.5)	38 (2.3)	42 (3.0)	42 (3.7)	39 (3.6)
49		Helmet Muff 2312 HF-5	MH	FP		7	15 (1.9)	16 (2.0)	21 (1.9)	29 (2.4)	37 (2.4)	43 (2.3)	43 (1.8)	40 (2.3)	37 (2.8)
50		Neckband Muff 2309 NF-1	MB	FP	R	7 (35)	10 (1.2)	10 (1.4)	19 (2.3)	32 (2.3)	35 (1.9)	40 (2.1)	41 (2.0)	41 (2.2)	41 (1.9)
51		Universal Liquid Muff 2301 UL-1	MO	LP		9 (45)	15 (2.2)	19 (2.9)	23 (3.0)	33 (2.2)	39 (2.3)	40 (1.5)	39 (3.3)	36 (2.7)	34 (1.4)
52		Universal Liquid Muff 2301 UL-1	MB	LP		9 (37)	14 (2.2)	17 (1.7)	22 (2.7)	31 (2.4)	38 (2.3)	40 (1.8)	39 (2.3)	37 (2.1)	34 (2.0)
53		Universal Liquid Muff 2301 UL-1	MU	LP		9 (37)	14 (2.0)	18 (2.0)	23 (1.5)	31 (2.5)	37 (2.8)	42 (2.4)	40 (2.6)	37 (1.8)	36 (2.6)

I.D. No.	Manufacturer or Supplier	Model	Design Code 1	2	3	Weight (Force) oz.	Average Attenuation in dB vs. Frequency in Hz (Standard Deviation in dB) 125	250	500	1000	2000	3150	4000	6300	8000
54a	Curtis Safety Products Co.	Noise-Checks	P1	VI	C		20	23	25	29	35	38	39	38	39
	91 Stafford Street	(V-51R)					(2.2)	(2.2)	(2.3)	(1.8)	(2.0)	(2.5)	(2.3)	(3.3)	(2.8)
55a	Worcester, MA 01603	Tri-Checks	P3	SI	C		23	25	30	34	37	39	42	41	40
	(617) 754-3906	(Triple Flange)					(2.6)	(2.0)	(3.1)	(2.3)	(2.3)	(2.4)	(1.4)	(2.8)	(3.0)
56	David Clark Company Inc.	27	MO	FM		16	23	26	26	31	31	34	35	36	36
	360 Franklin Street						(3.8)	(3.5)	(3.7)	(3.7)	(3.3)	(4.2)	(4.7)	(4.9)	(4.3)
57	Worcester, MA 01604	10A	MO	FM		14	11	21	29	33	36	37	38	37	37
	(617) 756-6216						(1.4)	(2.6)	(3.6)	(2.6)	(1.4)	(2.3)	(1.6)	(2.1)	(2.7)
58		805V	MB	FM	R	12	15	21	30	41	39	40	38	38	37
							(4.6)	(3.1)	(4.2)	(4.3)	(3.2)	(3.4)	(3.8)	(3.1)	(3.5)
59		730/731/732	MH	FH		11	17	20	27	34	35	34	34	36	35
							(3.0)	(2.9)	(4.6)	(5.1)	(3.9)	(4.0)	(3.5)	(5.1)	(3.7)
60a		705	MH	FH		11	12	17	30	35	35	36	37	32	30
							(2.5)	(3.0)	(4.6)	(5.6)	(4.5)	(4.3)	(4.2)	(4.1)	(2.9)
61		310 Tri-Fit	MO	FM		12	14	20	26	34	39	41	41	38	35
							(2.7)	(1.7)	(2.1)	(1.3)	(1.6)	(1.9)	(1.0)	(1.5)	(1.2)
62		310 Tri-Fit	MB	FM		12	8	15	24	31	36	39	40	39	35
							(2.1)	(2.3)	(2.8)	(1.7)	(1.6)	(2.0)	(1.7)	(1.7)	(1.4)
63		310 Tri-Fit	MU	FM		12	9	15	24	32	37	39	39	38	35
							(2.3)	(2.2)	(2.1)	(1.6)	(1.9)	(1.8)	(1.5)	(2.3)	(1.5)
64a		320 Tri-Fit	MO	FM		13	12	17	25	36	37	41	40	38	35
							(2.2)	(1.8)	(2.4)	(5.0)	(3.8)	(5.3)	(5.7)	(4.8)	(5.1)
65a		320 Tri-Fit	MB	FM		13	11	18	24	37	35	41	42	37	35
							(2.1)	(1.7)	(2.5)	(5.4)	(3.4)	(4.6)	(5.9)	(4.1)	(4.3)
66a		320 Tri-Fit	MU	FM		13	10	17	25	35	33	41	38	33	32
							(2.3)	(2.6)	(3.8)	(6.4)	(4.1)	(5.6)	(5.0)	(5.5)	(4.3)
67	E-A-R Division	E-A-R Plug	PE	FO	C		35	36	41	41	38	43	44	44	42
	7911 Zionsville Road	(PL-101)					(2.2)	(2.4)	(2.8)	(2.9)	(3.1)	(2.9)	(4.5)	(5.5)	(4.3)
68	Indianapolis, IN 46268	Caboflex Model 600	PC		B	1	22	22	23	28	32	37	89	41	41
	(317) 872-1111	(Under-the-Chin)				(5)	(3.1)	(2.7)	(2.3)	(2.4)	(2.8)	(3.3)	(3.6)	(4.8)	(4.9)
69		Caboflex Model 600	PC		B	1	21	22	23	27	32	37	39	40	41
		(Behind-the-Neck)				(5)	(3.1)	(3.0)	(2.3)	(2.2)	(2.6)	(3.4)	(2.9)	(4.8)	(5.1)
70	Earmark, Inc.	Type "H" Communi-	MO	FM	R	11	17	21	27	33	33	35	36	37	37
	1125 Dixwell Avenue	cation Earmuffs			A	(56)	(1.4)	(1.3)	(1.8)	(1.4)	(1.0)	(1.4)	(1.8)	(1.8)	(2.2)
	Hamden, CT 06514														
	(203) 777-2130														
71	Eastern Safety Equipment	EHP-1 510	MO	FN		9	12	20	28	39	40	36	36	39	39
	45-47 Pearson Street					(45)	(2.7)	(2.2)	(2.8)	(1.9)	(1.8)	(1.9)	(1.9)	(2.7)	(3.1)
72	Long Island C. NY 11101	510-2	MO	FP			19	19	30	40	38	36	34	37	38
	(212) 392-4100						(3.0)	(2.0)	(2.1)	(2.8)	(2.9)	(2.6)	(2.3)	(3.3)	(3.7)
73		986	PE	FO	D		36	38	41	39	37	45	44	44	45
							(3.9)	(3.0)	(2.3)	(2.7)	(2.8)	(3.2)	(4.1)	(4.2)	(4.8)
74		512	P1	VI			20	22	24	28	34	36	37	37	37
							(2.0)	(2.0)	(2.0)	(2.0)	(2.0)	(3.0)	(3.0)	(3.0)	(3.0)
75		509	CS	VI	B		10	15	17	20	31	34	31	31	31
							(2.0)	(2.0)	(1.8)	(1.9)	(2.8)	(2.1)	(2.0)	(1.9)	(3.4)
76	Erb Safety, Inc.	211	MO	FP		5	19	19	29	40	38	36	34	37	38
	529 Ga. Hwy. 5 North					(42)	(3.0)	(2.0)	(2.1)	(2.8)	(2.9)	(2.6)	(2.3)	(3.3)	(3.7)
77	Woodstock, GA 30188	213	MH	FH		6	13	14	22	32	37	35	34	32	33
	(404) 926-7944					(24)	(2.3)	(2.4)	(2.5)	(3.3)	(3.6)	(2.1)	(1.9)	(3.4)	(4.0)
78	Flents Products Co. Inc.	Anti-Noise	PU	WC	D		25	27	27	32	37	40	45	41	37
	14 Orchard Street	Ear Stopples					(2.6)	(2.9)	(3.1)	(3.1)	(3.2)	(2.9)	(5.3)	(4.9)	(4.8)
79	Norwalk, CT 06850	Quiet-Down	PU	GF	D		10	13	16	20	31	36	37	38	34
	(203) 866-2581						(2.4)	(1.6)	(1.9)	(1.9)	(1.9)	(1.6)	(2.4)	(2.1)	(1.4)
80		Silaflex	PU	SI	D		23	26	28	30	36	45	44	36	34
							(2.1)	(2.2)	(2.3)	(1.9)	(2.0)	(2.8)	(3.1)	(2.7)	(2.5)
81		Flexiplug	P5	SI	C		22	25	27	31	37	39	36	34	33
							(2.2)	(2.8)	(2.6)	(1.8)	(3.3)	(2.6)	(2.7)	(2.6)	(2.9)
82		V51R	P1	VI	C		20	23	25	29	35	39	39	38	39
							(2.2)	(2.2)	(2.3)	(1.8)	(2.0)	(2.5)	(2.3)	(3.3)	(2.8)
83		Silaplug	P3	SI	C		23	25	30	34	37	39	42	41	40
							(2.6)	(2.0)	(3.1)	(2.3)	(2.3)	(2.4)	(1.4)	(2.8)	(3.0)
84		Peace and Quiet	CS	VI	B		10	15	17	20	31	34	31	31	31
		Headband					(2.0)	(2.0)	(1.8)	(1.9)	(2.8)	(2.1)	(2.0)	(1.9)	(3.4)
85		Sila-Band Headband	CS	VI	B		16	17	20	26	31	34	32	29	30
		Over-the-Head					(2.4)	(2.8)	(3.2)	(3.2)	(2.7)	(1.6)	(1.9)	(2.7)	(3.7)
86		Sila-Band Headband	CS	VI	B		20	19	18	23	29	33	31	29	27
		Behind-the-Head					(2.7)	(2.1)	(2.6)	(2.0)	(2.9)	(2.5)	(3.2)	(2.5)	(2.5)
87		Sila-Band Headband	CS	VI	B		21	19	18	23	29	32	29	27	27
		Under-the-Chin					(3.1)	(2.8)	(2.8)	(1.9)	(2.3)	(2.3)	(1.9)	(1.9)	(2.9)
88		Silenta Universal	MO	FM		7	15	20	26	38	37	41	42	39	36
		Over-the-Head				(37)	(1.3)	(1.4)	(1.4)	(2.0)	(1.8)	(2.0)	(2.8)	(2.2)	(2.5)
89		Silenta Universal	MB	FM		7	14	19	24	35	36	42	43	37	34
		Behind-the-Head				(42)	(1.4)	(1.7)	(1.4)	(2.5)	(2.3)	(2.2)	(2.3)	(3.0)	(2.4)

I.D. No.	Manufacturer or Supplier	Model	Design Code 1	2	3	Weight (Force) oz.	125	250	500	1000	2000	3150	4000	6300	8000
							Average Attenuation in dB vs. Frequency in Hz (Standard Deviation in dB)								
90		Silenta Universal	MU	FM		7	14	19	24	35	36	42	42	37	35
		Under-the-Chin				(42)	(2.3)	(1.6)	(1.7)	(2.0)	(2.5)	(2.1)	(3.7)	(3.5)	(2.5)
91		Silenta Unicap	MH	FH		6	15	17	21	32	34	41	42	38	35
		Helmet Muff				(34)	(3.0)	(2.0)	(1.8)	(3.0)	(2.0)	(2.6)	(3.1)	(3.5)	(2.3)
92		Dielectric Muff	MO	FP		5	19	19	29	40	38	36	34	37	38
		Over-the-Head				(42)	(3.0)	(2.0)	(2.1)	(2.8)	(2.9)	(2.6)	(2.3)	(3.3)	(3.7)
93		Dielectric Muff	MU	FP		5	12	14	21	34	34	35	34	37	37
		Behind-the-Head				(45)	(3.5)	(2.6)	(4.7)	(6.2)	(4.6)	(2.6)	(2.2)	(2.7)	(2.2)
94		Dielectric Muff	MU	FP		5	12	14	22	33	34	33	32	35	38
		Under-the-Chin				(45)	(3.9)	(2.7)	(4.9)	(6.2)	(4.4)	(3.4)	(3.3)	(2.4)	(2.0)
95	Glendale Optical Co. Inc.	GN900, GN901	MO	FP		10	13	16	23	33	37	40	42	39	35
	130 Crossways Park Drive					(46)	(1.2)	(1.4)	(1.4)	(1.0)	(1.4)	(1.8)	(2.1)	(2.1)	(1.5)
96	Woodbury, NY 11797	GN900, GN901	MB	FP		10	12	16	23	31	34	37	39	36	34
	(516) 921-5800					(54)	(1.3)	(1.9)	(2.1)	(1.2)	(1.3)	(1.9)	(2.5)	(1.5)	(1.3)
97		GN900, GN901	MU	FP		10	13	17	22	31	35	40	41	38	39
						(72)	(1.2)	(1.8)	(1.9)	(1.9)	(0.9)	(1.8)	(1.4)	(2.0)	(1.8)
98		GN920	MO	FP		8	12	14	23	33	36	42	39	39	40
						(61)	(4.1)	(2.9)	(2.0)	(1.8)	(2.5)	(2.7)	(2.9)	(3.3)	(3.2)
99		GN920	MB	FB		8	11	14	23	32	37	41	38	40	39
						(62)	(2.8)	(2.4)	(2.0)	(2.3)	(2.9)	(3.4)	(2.1)	(2.7)	(3.7)
100		GN920	MU	FP		8	11	14	23	33	35	41	38	39	39
						(62)	(2.7)	(1.8)	(1.5)	(1.8)	(2.8)	(3.5)	(2.7)	(3.5)	(4.0)
101		GN930H	MH	FP		8	8	10	19	27	31	32	31	30	28
						(18)	(3.3)	(2.6)	(3.2)	(3.0)	(3.5)	(5.7)	(5.4)	(4.1)	(3.3)
102	Hearing Control Inc.	RC 31.3	PS	VI	C		32	33	35	36	39	44	45	45	43
	P.O. Box 1427						(3.3)	(2.4)	(2.4)	(2.4)	(2.5)	(3.5)	(3.0)	(2.7)	(4.4)
	Clarksville, TX 75426														
	(214) 427-5685														
103	H. E. Douglass Eng. Sales Co.	Sound Sentry	CS		B		23	21	19	23	32	35	33	31	29
	10861 Sherman Way	Canal Cap 7500B-1					(3.8)	(3.9)	(3.4)	(2.8)	(3.1)	(2.6)	(3.7)	(5.5)	(4.4)
104	Sun Valley, CA 91352	Sound Sentry	CS		B		18	17	16	19	30	33	30	27	25
	(213) 875-3144	Canal Cap 7500B					(7.6)	(7.8)	(5.5)	(4.2)	(4.2)	(4.5)	(5.7)	(8.0)	(7.3)
105d	H. S. Leight & Associates	Air Soft, AS-1,	P3	VI	C		23	25	29	32	35	40	43	40	38
	1705 East 20th Street	AS-30R					(1.6)	(1.7)	(2.0)	(2.0)	(2.7)	(2.1)	(2.9)	(3.1)	(3.0)
106d	Los Angeles, CA 90058	Quiet, QD-1, QD-30	PN	VI	C		31	32	32	33	34	40	43	46	45
	(213) 746-2234						(3.6)	(4.3)	(2.7)	(3.1)	(4.3)	(4.9)	(4.0)	(5.1)	(5.6)
107d		Quiet Band, QB2	PC	VI	B		22	23	25	31	39	43	45	45	46
		(Under-the-Chin)					(3.0)	(2.9)	(2.1)	(2.2)	(2.8)	(3.4)	(3.4)	(4.6)	(4.8)
108d		Quiet Band, QB2	PC	VI	B		22	22	24	30	38	40	42	42	43
		(Behind-the-Head)					(3.1)	(3.0)	(2.2)	(2.1)	(2.6)	(3.5)	(3.6)	(4.7)	(5.0)
109	Hocks Laboratories	Noise Braker	PS	SI	C		10	13	23	30	34	43	41	33	33
	935 N.E. Couch	Filtered					(1.8)	(1.7)	(2.7)	(2.1)	(1.8)	(2.1)	(2.4)	(3.1)	(2.5)
110	Portland, OR 97214	Noise Braker	PS	SI	C		29	31	36	38	38	44	45	39	37
	(800) 547-3669	Solid					(2.8)	(3.0)	(2.4)	(2.1)	(2.3)	(2.9)	(2.1)	(3.3)	(3.0)
111c	Insta-Mold Prosthetics	Inst-Mold	PS	SI			22	26	27	25	41	48	48	52	37
	P.O. Box 2146	Noise Guard					(4.0)	(4.3)	(5.5)	(4.4)	(3.0)	(8.0)	(6.2)	(6.5)	(5.5)
	Boulder, CO 80306														
	(303) 447-2619														
112	Mediprint Inc.	V51R Single Flange	PI	VI	C		20	23	25	29	35	38	39	38	39
	P.O. Box 904						(2.2)	(2.2)	(2.3)	(1.8)	(2.0)	(2.5)	(2.3)	(3.3)	(2.8)
113	Wallingford, CT 05492	Triple Flange	P3	SI	C		23	25	30	34	37	39	42	41	40
	(203) 265-2110						(2.6)	(2.0)	(3.1)	(2.3)	(2.3)	(2.4)	(1.4)	(2.8)	(3.0)
114		Foam	PE	FO			35	37	40	38	37	42	42	44	45
							(3.0)	(3.1)	(3.3)	(2.2)	(1.5)	(2.3)	(2.9)	(3.7)	(4.0)
115	Midland Optical Inc.	960	MO	FP		7	17	20	25	33	37	38	36	34	32
	412 N. East Street					(37)	(1.8)	(2.1)	(2.3)	(1.9)	(2.1)	(2.2)	(2.4)	(2.1)	(2.0)
116	Coudersport PA 16915	960	MB	FP		7	15	17	24	33	34	36	34	31	29
	(814) 274-8581					(37)	(3.9)	(4.0)	(2.2)	(3.2)	(2.5)	(2.7)	(2.8)	(3.3)	(3.5)
117		960	MU	FP		7	13	17	23	33	34	35	33	30	29
						(37)	(3.7)	(4.3)	(3.2)	(3.1)	(2.5)	(2.5)	(2.6)	(3.3)	(4.0)
118	Mine Safety Appliances Co.	Ear Defenders	PI	VI			26	26	25	30	34	40	38	34	32
	600 Penn Center Blvd.						(3.6)	(3.4)	(3.8)	(2.9)	(3.1)	(3.3)	(4.8)	(4.8)	(4.5)
119	Pittsburgh, PA 15235	Accu-Fit	P3	SI			29	28	29	33	36	40	37	36	35
	(412) 273-5170						(3.5)	(2.7)	(2.2)	(1.9)	(3.0)	(3.6)	(4.0)	(2.6)	(3.3)
120		Ear Defenders II	P2	VI			30	30	29	34	39	42	42	40	38
							(3.3)	(3.2)	(2.8)	(2.9)	(3.4)	(2.9)	(4.8)	(5.7)	(4.1)
121		Comfo 500	MO	FP		6	11	17	21	25	32	36	37	35	34
						(48)	(2.4)	(2.3)	(2.1)	(1.8)	(2.6)	(2.6)	(2.5)	(3.5)	(4.3)
122		Comfo 500	MB	FP		6	10	15	20	25	31	35	35	35	32
						(48)	(1.6)	(2.7)	(1.8)	(2.7)	(2.5)	(3.2)	(3.2)	(4.4)	(4.6)
123		Comfo 500	MU	FP		6	9	16	21	24	31	36	37	36	32
						(48)	(1.6)	(3.1)	(2.0)	(2.4)	(2.6)	(3.0)	(2.6)	(4.2)	(3.9)
124		Noisefoe Mark II	MO	FM		11	15	21	29	35	37	37	37	37	36
						(59)	(2.2)	(1.8)	(2.0)	(1.6)	(2.1)	(1.9)	(2.4)	(3.1)	(2.2)

I.D. No.	Manufacturer or Supplier	Model	Design Code 1	Design Code 2	Design Code 3	Weight (Force) oz.	125	250	500	1000	2000	3150	4000	6300	8000
							Average Attenuation in dB vs. Frequency in Hz (Standard Deviation in dB)								
125		Noisefoe Mark IV	MO	FM		11 (29)	14 (2.2)	19 (1.4)	28 (1.9)	34 (1.7)	36 (2.2)	40 (3.0)	40 (3.0)	40 (2.6)	40 (3.9)
126		Noisefoe Mark IV	MB	FM		11 (39)	14 (1.7)	21 (1.5)	27 (3.3)	32 (2.7)	37 (2.2)	42 (2.2)	44 (1.8)	40 (2.1)	38 (2.8)
127		Noisefoe Mark IV	MU	FM		11 (39)	14 (1.5)	20 (2.1)	26 (3.2)	31 (1.7)	35 (2.3)	41 (2.3)	43 (1.9)	39 (2.5)	37 (2.5)
128		Noisefoe Mark IVMC	MO	FM		11 (59)	14 (1.8)	21 (1.6)	28 (1.9)	37 (1.8)	41 (2.0)	41 (2.8)	41 (2.2)	41 (1.4)	40 (2.6)
129		Noisefoe Mark IVMC	MB	FM		11 (60)	11 (2.8)	15 (2.0)	26 (2.8)	35 (3.1)	38 (3.0)	39 (3.0)	40 (2.9)	40 (2.4)	39 (2.8)
130		Noisefoe Mark IVMC	MU	FM		11 (60)	10 (3.8)	15 (2.3)	26 (2.6)	34 (2.2)	37 (2.2)	39 (2.3)	38 (1.7)	39 (2.9)	37 (2.9)
131		Mark IV Kit on Skull Gard Cap	MU	FM		10 (42)	14 (2.2)	19 (2.1)	28 (2.3)	38 (1.5)	40 (1.7)	42 (1.8)	41 (1.4)	40 (1.8)	39 (2.0)
132		Mark V Kit on Topgard Cap	MH	FM		9 (30)	15 (2.6)	20 (1.5)	28 (1.9)	35 (2.5)	33 (2.1)	35 (2.8)	33 (2.6)	33 (2.7)	32 (3.0)
133		Noisefoe Mark V	MO	FP		9 (48)	15 (1.7)	23 (1.5)	30 (1.8)	38 (2.1)	36 (1.8)	38 (2.5)	38 (1.5)	37 (2.4)	35 (2.9)
134		Noisefoe Mark V	MB	FP	R	9 (52)	15 (1.5)	22 (2.6)	29 (1.8)	37 (2.0)	38 (2.8)	40 (3.1)	39 (2.7)	36 (2.6)	36 (3.2)
135		Noisefoe Mark V	MU	FP	R	9 (52)	15 (1.4)	23 (2.6)	31 (2.1)	37 (2.6)	38 (2.2)	40 (2.7)	38 (3.1)	37 (2.5)	36 (3.1)
136		Noisefoe Mark V	MB	FP		9 (49)	12 (1.9)	21 (1.4)	29 (2.5)	38 (3.1)	36 (1.6)	42 (3.5)	39 (2.4)	36 (2.8)	35 (2.4)
137		Noisefoe Mark V	MU	FP		9 (49)	12 (1.4)	22 (1.4)	30 (2.1)	39 (2.7)	36 (1.6)	42 (3.2)	39 (2.2)	36 (2.4)	36 (3.1)
138		Mark V Kit on Skull Gard Cap	MH	FP		9 (42)	18 (2.9)	22 (1.5)	30 (2.3)	38 (2.9)	37 (2.7)	41 (3.5)	39 (3.1)	39 (3.5)	37 (3.6)
139		Mark V Kit on V-Gard Cap	MH	FP		9 (37)	14 (2.6)	21 (1.5)	28 (1.8)	34 (2.2)	33 (2.3)	36 (2.6)	34 (2.6)	32 (4.0)	32 (3.8)
140		Mark V on V-Gard Cap w/Faceshield	MH	FP		14 (40)	17 (3.1)	20 (2.1)	29 (2.9)	37 (2.6)	37 (3.6)	41 (2.8)	40 (3.2)	39 (2.3)	37 (3.2)
141		Mark V on Topgard Cap w/Faceshield	MH	FP		14 (40)	14 (3.0)	18 (2.7)	26 (3.2)	34 (3.0)	36 (2.9)	39 (3.8)	39 (3.3)	36 (4.9)	35 (4.6)
142	Moldex-Metric Inc. 4671 Leahy Street Culver City, CA 90230 (213) 870-9121	Pura-Foam #6600	PE	FO	D		36 (3.9)	38 (3.0)	41 (2.3)	39 (2.7)	37 (2.8)	45 (3.2)	44 (4.1)	44 (4.2)	41 (4.8)
143	Peltor Inc. 871 Waterman Avenue	Peltor H7P3E, on MSA V-Gard Cap	MH	LM		9 (37)	14 (2.1)	19 (2.0)	28 (3.0)	36 (2.1)	36 (2.2)	38 (2.3)	35 (2.1)	35 (2.1)	36 (2.4)
144	E. Providence, RI 02914 (401) 438-4800	Peltor H7B	MB	LM		7 (38)	14 (3.5)	20 (3.4)	27 (2.8)	38 (3.3)	38 (3.0)	39 (2.2)	35 (3.5)	34 (3.7)	35 (4.0)
145		Peltor H9P3E, on MSA V-Gard Cap	MH	FM		6 (26)	10 (2.3)	15 (2.4)	23 (2.7)	33 (2.7)	36 (3.2)	39 (3.2)	36 (2.9)	33 (3.6)	32 (3.3)
146		Peltor H3A	MO	LM		7 (30)	14 (3.3)	21 (3.6)	28 (3.6)	38 (3.1)	37 (3.0)	38 (2.9)	34 (2.8)	32 (3.1)	33 (3.7)
147		Peltor H3P3E, on MSA V-Gard Cap	MH	LM		3 (29)	14 (2.7)	20 (2.8)	27 (3.7)	37 (3.2)	37 (3.1)	39 (2.4)	34 (2.3)	32 (2.6)	32 (3.7)
148		Peltor H6A	MO	FM		6 (50)	12 (1.9)	13 (2.2)	23 (1.6)	32 (2.5)	35 (3.2)	44 (3.6)	39 (2.6)	39 (2.4)	37 (2.8)
149		Peltor H6F	MO	FM		6 (50)	13 (2.1)	13 (1.4)	23 (1.4)	32 (2.2)	35 (2.3)	44 (3.1)	40 (1.4)	40 (3.2)	38 (3.8)
150		Peltor H6P3E, on MSA V-Gard Cap	MH	FM		5 (54)	11 (2.1)	14 (1.9)	24 (1.9)	32 (2.9)	34 (2.3)	42 (3.4)	40 (2.5)	38 (2.7)	36 (3.8)
151		Peltor H6-B	MB	FM		6	11 (3.1)	14 (2.0)	23 (2.9)	32 (3.6)	34 (3.0)	43 (2.3)	40 (2.5)	37 (2.5)	36 (4.0)
152		Peltor H7-A	MO	LM		8	17 (2.8)	24 (1.8)	30 (1.9)	38 (2.2)	40 (2.1)	45 (3.7)	40 (2.6)	39 (3.9)	38 (3.8)
153		Peltor H9A	MO	FM		5 (34)	13 (1.4)	16 (2.7)	25 (2.2)	32 (2.0)	37 (2.3)	39 (1.9)	38 (1.3)	35 (2.0)	34 (2.6)
154		Peltor Bullseye "9"	MO	FM		5 (34)	13 (1.4)	16 (2.7)	25 (2.2)	32 (2.0)	37 (2.3)	39 (1.9)	38 (1.3)	35 (2.0)	34 (2.6)
155		Peltor Bullseye "6"	MO	LM		6	13 (2.1)	13 (1.4)	23 (1.4)	32 (2.2)	35 (2.3)	48 (3.1)	40 (1.4)	40 (3.2)	38 (3.8)
156		Peltor Bullseye "7"	MO	LM		8	17 (2.8)	24 (1.8)	30 (1.9)	38 (2.2)	40 (2.1)	45 (3.7)	40 (2.6)	39 (3.9)	38 (3.8)
157	Plasmed Inc. 145 N. Plains Ind. Pk. Rd.	V51R Single Flange	P1	VI	C		20 (2.2)	23 (2.2)	25 (2.3)	29 (1.8)	35 (2.0)	38 (2.5)	39 (2.3)	39 (3.3)	39 (2.8)
158	Wallingford, CT 06492 (203) 265-6761	Triple Flange	P3	SI	C		23 (2.6)	25 (2.0)	30 (3.1)	34 (2.3)	37 (2.3)	39 (2.4)	42 (1.4)	41 (2.8)	40 (3.0)
159		Foam	PE	FO			35 (3.0)	37 (3.1)	40 (3.3)	38 (2.2)	37 (1.5)	42 (2.3)	42 (2.9)	44 (3.7)	45 (4.0)
160	Pulmosan Safety Equipment 30-48 Linden Place	80336	MO	FM		14 (34)	11 (1.4)	21 (2.6)	29 (3.6)	33 (2.6)	36 (1.4)	37 (2.3)	38 (1.6)	37 (2.1)	37 (2.7)
161a	Flushing, NY 11354 (212) 939-3200	80339	MH	FM		11	12 (2.5)	17 (3.0)	30 (4.6)	35 (5.6)	35 (4.5)	36 (4.3)	37 (4.2)	32 (4.1)	30 (2.9)

I.D. No.	Manufacturer or Supplier	Model	Design Code 1	Design Code 2	Design Code 3	Weight (Force) oz.	125	250	500	1000	2000	3150	4000	6300	8000
							Average Attenuation in dB vs. Frequency in Hz (Standard Deviation in dB)								
162		80342	MB	FM		12 (59)	15 (4.6)	21 (3.1)	30 (4.2)	41 (4.3)	39 (3.2)	40 (3.4)	38 (3.8)	38 (3.1)	37 (3.5)
163		80720	PU	SI	D		23 (2.1)	26 (2.2)	28 (2.3)	30 (1.9)	36 (2.0)	45 (2.8)	44 (3.1)	36 (2.7)	34 (2.5)
164		80786	PN	VI	B		10 (2.0)	15 (2.0)	17 (1.8)	23 (1.9)	31 (2.8)	34 (2.1)	38 (2.0)	38 (1.9)	31 (3.4)
165		80792	MO	FM		9 (45)	12 (2.7)	20 (2.2)	28 (2.8)	39 (1.9)	40 (1.8)	36 (1.9)	36 (1.9)	39 (2.7)	39 (3.1)
166		80792	MB	FM		9 (40)	12 (2.6)	19 (2.3)	26 (2.5)	35 (1.8)	37 (1.7)	36 (1.5)	36 (1.5)	36 (1.8)	35 (1.9)
167		80792	MU	FM		9 (40)	12 (2.9)	19 (2.4)	26 (1.6)	35 (1.5)	38 (1.4)	37 (1.8)	37 (2.3)	36 (2.7)	35 (2.3)
168		80795, 80798, 80801 80804, 80807, 80810	P3	SI	C		23 (2.6)	25 (2.0)	30 (3.1)	34 (2.3)	37 (2.3)	39 (2.4)	42 (1.4)	41 (2.8)	40 (3.0)
169	Safeco Manufacturing Ltd. 947 Warden Avenue	Cap Mounted Model 970	MH	FP	R	7 (24)	11 (2.2)	14 (2.8)	21 (3.7)	29 (3.2)	33 (3.1)	38 (4.1)	36 (3.9)	33 (3.6)	32 (5.6)
170	Scarborough, ONT M1L 4E3 (416) 752-6740	Overhead Model 204	MO	FP	R	6 (24)	11 (2.4)	19 (3.5)	25 (3.1)	33 (2.6)	37 (2.6)	41 (3.2)	40 (3.8)	35 (3.7)	33 (3.7)
171		Overhead Model 290	MO	FM	R	9 (37)	16 (1.8)	19 (2.1)	27 (3.4)	36 (3.9)	38 (2.6)	42 (3.1)	41 (3.5)	37 (3.0)	35 (3.4)
172		Overhead Model 304	MO	LP	R	9 (26)	17 (4.2)	19 (3.4)	24 (3.0)	36 (2.3)	38 (2.0)	38 (2.0)	37 (3.0)	35 (2.9)	33 (4.0)
173		Overhead Model 258	MO	LM	R	11 (37)	18 (3.6)	22 (3.5)	26 (3.5)	34 (3.0)	36 (3.1)	39 (4.3)	39 (5.0)	37 (4.2)	35 (4.8)
174	Safety Direct Inc. 23 Snider Way	Silencio Mach II Pt No CD8-80	MO	LM		12 (68)	21 (2.4)	26 (1.7)	32 (1.4)	41 (2.0)	42 (2.4)	43 (2.6)	39 (2.7)	35 (2.9)	36 (2.7)
175	Sparks, NV 89431 (702) 359-4451	Silencio Mach I Pt No CD8-81	MO	FM		10 (68)	14 (3.0)	19 (1.9)	27 (1.7)	35 (2.3)	33 (2.0)	42 (1.6)	34 (2.0)	32 (1.9)	33 (1.7)
176		Silencio Pt No RBW-71	MO	FM		9 (53)	17 (2.3)	22 (2.0)	27 (2.7)	37 (2.8)	39 (2.9)	41 (2.0)	38 (2.1)	36 (2.2)	36 (2.1)
177		Silencio Pt No RBW-71	MU	FM		9 (67)	17 (2.1)	19 (1.8)	28 (3.1)	36 (2.3)	39 (2.2)	42 (2.0)	37 (2.1)	36 (2.5)	35 (1.7)
178		Silencio Pt No RBW-71	MB	FM		9 (67)	14 (2.9)	19 (2.4)	27 (2.8)	36 (2.9)	38 (2.6)	41 (3.2)	37 (2.3)	36 (2.5)	35 (2.7)
179		Silencio Liquid Pt No LIQ-71	MO	LM		11 (53)	20 (2.3)	25 (2.0)	31 (2.3)	38 (2.2)	41 (2.4)	41 (2.8)	37 (1.8)	36 (1.6)	36 (2.8)
180		Silencio Liquid Pt No L10-71	MU	LM		11 (67)	13 (2.3)	19 (3.5)	25 (3.0)	31 (3.2)	34 (2.5)	36 (2.5)	34 (2.2)	35 (1.9)	34 (1.8)
181		Silencio Liquid Pt No LIQ-71	MO	LM		11 (67)	17 (2.6)	20 (3.3)	27 (2.3)	33 (2.6)	36 (2.0)	39 (2.1)	37 (2.6)	35 (2.3)	35 (1.9)
182		SDI 100, 101	P2	VI	C		27 (3.9)	19 (2.9)	31 (3.0)	33 (3.0)	37 (4.0)	43 (3.4)	45 (3.6)	40 (4.2)	36 (4.3)
183	Sellstrom Mfg. Company 220 South Hicks Road Palatine, IL 60067 (312) 358-2000	404 Tonedown II Hearing Protector	MO	FP	R	13 (62)	11 (2.0)	15 (1.9)	24 (1.5)	32 (1.6)	35 (3.0)	43 (1.9)	39 (2.0)	36 (2.2)	35 (1.7)
184	Siebe Norton 2000 Plainfield Pike	Com-Fit	P3	SI			30 (3.0)	28 (3.3)	30 (3.5)	32 (2.2)	34 (2.0)	40 (2.5)	42 (4.1)	46 (4.5)	46 (4.6)
185	Cranston, RI 02920 (401) 943-4400	Silent Partner	PN	SI			18 (2.8)	24 (2.5)	27 (1.9)	30 (1.6)	37 (2.5)	42 (1.4)	42 (1.7)	42 (1.7)	42 (2.2)
186		Peacekeeper	PS	SI			9 (1.8)	13 (1.3)	14 (1.3)	19 (1.4)	28 (1.9)	33 (2.2)	35 (2.6)	29 (2.8)	27 (2.1)
187		Sonic Ear Valv 'For Impact Noise'	P3	SI			7 (2.5)	6 (3.0)	5 (2.4)	13 (2.3)	23 (2.8)	23 (2.2)	21 (2.8)	28 (3.4)	24 (3.2)
188		Silent Band-It Over-the-Head	PN	SI	B		18 (3.4)	23 (2.1)	27 (1.5)	30 (1.8)	36 (1.7)	42 (2.0)	42 (1.5)	42 (2.2)	42 (2.7)
189		Silent Band-It Behind-the-Head	PN	SI	B		18 (2.1)	24 (2.8)	27 (2.3)	30 (1.6)	36 (1.3)	41 (1.8)	42 (1.9)	41 (2.7)	38 (2.4)
190		Silent Band-It Under-the-Chin	PN	SI	B		17 (1.9)	22 (1.7)	25 (1.7)	29 (1.5)	36 (1.5)	40 (1.5)	41 (1.4)	41 (2.2)	38 (1.7)
191		#4540	MO	FM		11	14 (3.1)	23 (2.7)	32 (2.5)	41 (2.9)	36 (2.5)	34 (2.3)	34 (2.7)	36 (2.2)	39 (2.3)
192		#4540	MB	FM		11	15 (3.5)	22 (3.2)	31 (2.4)	40 (3.9)	34 (2.9)	34 (2.6)	33 (2.7)	34 (4.5)	34 (4.8)
193		#4540	MU	FM		11	18 (3.8)	23 (2.5)	30 (3.0)	39 (3.5)	34 (2.9)	33 (3.1)	32 (2.5)	39 (4.1)	37 (3.6)
194		#4530	MO	FM		12	15 (2.1)	21 (2.4)	29 (2.3)	40 (2.5)	42 (2.5)	42 (2.9)	43 (3.5)	41 (4.0)	40 (4.0)
195		#4530	MB	FM		12	14 (2.7)	20 (3.1)	27 (3.5)	37 (2.5)	39 (2.3)	42 (3.9)	43 (3.9)	42 (2.5)	40 (3.9)
196		#4530	MU	FM		12	14 (3.0)	20 (3.1)	28 (2.9)	36 (2.7)	38 (2.7)	41 (3.9)	42 (3.6)	42 (3.9)	40 (4.4)
197		#4520	MO	FM		11	13 (3.3)	19 (3.3)	25 (2.6)	35 (2.6)	38 (2.5)	40 (2.6)	40 (2.9)	40 (3.3)	40 (4.3)
198		#4520	MB	FM		11	12 (3.0)	17 (1.7)	25 (2.2)	35 (2.0)	36 (1.7)	38 (2.6)	39 (3.0)	38 (3.6)	37 (4.2)

I.D. No.	Manufacturer or Supplier	Model	Design Code 1	2	3	Weight (Force) oz.	125	250	500	1000	2000	3150	4000	6300	8000
							Average Attenuation in dB vs. Frequency in Hz (Standard Deviation in dB)								
199		#4520	MU	FM		11	12 (2.6)	18 (2.8)	24 (2.7)	34 (2.1)	36 (1.7)	38 (3.1)	37 (2.9)	38 (3.6)	37 (3.0)
200	Tasco Corporation 37 Tripps Lane	T-250, T-250S	MO	FM		9 (45)	12 (2.7)	20 (2.2)	28 (2.8)	39 (1.9)	40 (1.8)	36 (1.9)	36 (1.9)	39 (1.7)	39 (3.1)
201	East Providence, RI 02915 (401) 438-9200	T-250, T-250S (T-250A-Ret. Strap)	MB	FM		9 (40)	12 (2.6)	19 (2.3)	26 (2.5)	35 (1.8)	37 (1.7)	36 (1.5)	36 (1.5)	36 (1.8)	35 (1.9)
202		T-250, T-250S	MU	FM		9 (40)	12 (2.9)	19 (2.4)	26 (1.6)	35 (1.5)	38 (1.4)	37 (1.8)	37 (2.3)	36 (2.7)	35 (2.3)
203		T-100, T-100S	CS	VI	B		10 (2.0)	15 (2.0)	17 (1.8)	20 (1.9)	31 (2.8)	34 (2.1)	31 (2.0)	31 (1.9)	31 (3.4)
204		Swivel Band, - Defense, O-T-H	CS	VI	B		16 (2.4)	17 (2.8)	20 (3.2)	26 (3.2)	31 (2.7)	34 (1.6)	32 (1.9)	29 (2.7)	30 (3.7)
205		Swivel Band, - Defense, B-T-H	CS	VI	B		20 (2.7)	19 (2.1)	18 (2.6)	23 (2.0)	29 (2.9)	33 (2.5)	31 (3.2)	29 (2.5)	27 (3.5)
206		Swivel Band, - Defense, U-T-C	CS	VI	B		21 (3.1)	19 (2.8)	18 (2.8)	23 (1.9)	29 (2.3)	32 (2.3)	29 (1.9)	27 (1.9)	27 (2.9)
207		T-300, T-300S	MB	FP		6 (53)	8 (2.4)	14 (2.2)	19 (2.4)	26 (1.7)	34 (1.8)	38 (3.4)	37 (3.8)	33 (3.6)	31 (3.0)
208		T-300, T-300S	MU	FP		6 (53)	7 (1.9)	13 (1.9)	17 (2.6)	24 (3.0)	29 (3.9)	33 (5.1)	32 (5.6)	28 (4.1)	26 (4.5)
209		RD-1 Safety Cone	PC	VI	D C		27 (3.4)	27 (3.4)	38 (4.4)	32 (3.4)	37 (2.8)	42 (3.4)	38 (4.6)	36 (3.4)	34 (3.6)
210		H-1 Ear Plug (XS, S, M, L, XL)	P1	VI	C		20 (2.0)	22 (2.0)	24 (2.0)	28 (2.0)	34 (2.0)	36 (3.0)	37 (3.0)	37 (3.0)	37 (3.0)
211		T-520, on Jackson Prod. SC-6 S.-Cap	MH	FH		9	10 (2.9)	18 (2.7)	25 (2.8)	34 (2.5)	36 (2.4)	35 (2.5)	36 (3.1)	37 (3.2)	35 (3.2)
212		Tri-Gard Earplug (S, M, L)	P3	SI	C		22 (2.6)	24 (2.0)	29 (3.1)	33 (2.3)	36 (2.3)	38 (2.4)	41 (1.4)	40 (2.8)	39 (3.0)
213	Telex Communications, Inc. 9600 Aldrich Avenue South Minneapolis, MN 55420 (612) 884-4051	HD-3 63700-002; HD-4 63700-007	MO	FM	A	19 (52)	12 (3.2)	19 (2.2)	21 (1.8)	33 (2.1)	33 (2.8)	36 (2.7)	36 (2.7)	37 (3.5)	37 (3.9)
214	Willson Safety Products 2nd & Washington Streets, Box 622	459A/459AL Sound Barrier	MO	LM	A	15/13 (30)	19 (3.8)	23 (3.3)	24 (2.7)	33 (2.2)	33 (3.0)	32 (3.4)	33 (3.3)	34 (2.6)	35 (3.6)
215	Reading, PA 19603 (215) 376-6161	460A Sound Barrier	MO	LM	A	22 (35)	20 (3.3)	23 (2.5)	25 (3.6)	34 (2.4)	34 (2.3)	34 (2.5)	35 (3.3)	36 (3.7)	37 (2.9)
216		460CU-2 Sound Barrier	MO	LM	A	23 (35)	18 (3.4)	19 (2.8)	22 (2.5)	33 (2.2)	34 (2.6)	37 (7.3)	36 (4.2)	33 (3.5)	33 (4.3)
217		462A Sound Barrier	MO	LM	A	18 (35)	21 (3.4)	23 (2.5)	23 (3.3)	34 (2.5)	34 (1.8)	34 (2.2)	35 (3.3)	37 (4.1)	37 (3.2)
218		390 Sound Barrier	MH			9 (29)	12 (2.9)	18 (2.2)	25 (2.0)	35 (2.2)	35 (2.3)	34 (3.0)	37 (2.8)	37 (3.4)	34 (2.8)
219		390A/390AL Sound Barrier	MH		A	10/12 (29)	15 (2.0)	19 (2.5)	26 (2.2)	36 (2.4)	38 (2.0)	34 (2.3)	37 (3.0)	38 (3.7)	35 (2.6)
220		381A Sound Barrier	MO	LM		11 (43)	13 (2.2)	17 (2.6)	27 (2.4)	34 (1.5)	37 (1.6)	38 (1.9)	38 (1.8)	40 (2.0)	41 (1.9)
221		381A Sound Barrier	MB	LM	R	11 (49)	12 (2.0)	16 (2.0)	23 (1.4)	30 (1.9)	36 (1.7)	37 (1.7)	37 (1.9)	38 (2.3)	40 (2.2)
222		381A Sound Barrier	MU	LM	R	11 (49)	11 (1.8)	15 (1.9)	22 (2.2)	30 (1.9)	35 (1.6)	36 (2.1)	37 (2.2)	37 (2.0)	35 (2.1)
223		381 Sound Barrier	MO	FM		9 (46)	10 (1.9)	14 (2.3)	21 (2.5)	31 (2.3)	34 (2.4)	37 (1.7)	37 (2.4)	40 (1.7)	40 (2.0)
224		381 Sound Barrier	MB	FM	R	9 (53)	9 (1.7)	14 (1.8)	21 (2.2)	29 (2.2)	34 (1.9)	36 (1.7)	37 (1.7)	39 (2.6)	39 (2.6)
225		381 Sound Barrier	MU	FM	R	9 (53)	9 (2.1)	13 (2.0)	20 (1.8)	29 (2.0)	34 (1.6)	35 (1.8)	36 (1.7)	36 (1.9)	35 (1.7)
226		365A Sound Barrier	MO	LP		11 (56)	21 (1.5)	21 (2.2)	29 (2.9)	38 (2.8)	39 (2.0)	38 (1.9)	38 (1.4)	39 (1.5)	40 (2.2)
227		365A Sound Barrier	MB	LP		11 (54)	18 (3.5)	23 (1.8)	29 (2.3)	37 (2.7)	37 (1.9)	36 (1.5)	38 (1.9)	38 (1.7)	39 (2.1)
228		365A Sound Barrier	MU	LP		11 (54)	18 (2.5)	22 (3.1)	29 (1.8)	35 (3.3)	36 (1.7)	37 (2.1)	37 (2.7)	39 (2.3)	39 (2.4)
229		365 Sound Barrier	MO	FP		9 (61)	17 (1.9)	20 (2.5)	30 (3.6)	38 (2.9)	39 (2.0)	37 (1.9)	38 (1.4)	40 (2.3)	40 (3.1)
230		365 Sound Barrier	MB	FP		9 (61)	14 (2.7)	19 (2.8)	29 (3.1)	36 (3.6)	37 (2.1)	36 (1.8)	37 (2.2)	39 (1.9)	38 (2.2)
231		365 Sound Barrier	MU	FP		9 (61)	13 (2.4)	18 (2.9)	27 (4.0)	34 (3.3)	36 (1.9)	36 (2.0)	37 (2.2)	39 (1.7)	38 (2.7)
232		358A Sound Barrier	MO	LM		11 (46)	14 (1.9)	17 (2.0)	24 (2.5)	34 (1.6)	32 (1.8)	30 (1.4)	33 (1.4)	31 (1.6)	27 (1.7)
233		351A Sound Barrier	MO	LM		12 (46)	15 (2.1)	20 (1.8)	25 (2.1)	34 (2.6)	34 (1.5)	31 (1.4)	32 (1.4)	30 (2.0)	28 (2.7)
234		351 Sound Barrier	MO	FM		10 (53)	11 (2.2)	16 (2.7)	23 (2.4)	32 (2.5)	33 (2.0)	33 (1.8)	34 (1.7)	28 (3.5)	25 (3.5)
235		155 Sound Barrier	MB	FM	R	7	11 (2.6)	15 (1.6)	21 (2.1)	31 (2.1)	35 (2.4)	41 (2.5)	35 (1.9)	31 (2.6)	32 (2.3)

I.D. No.	Manufacturer or Supplier	Model	Design Code 1	2	3	Weight (Force) oz.	Average Attenuation in dB vs. Frequency in Hz (Standard Deviation in dB) 125	250	500	1000	2000	3150	4000	6300	8000
236		155A Sound Barrier	MB	LM	R	9	17	20	25	33	37	41	36	34	34
						(35)	(3.3)	(2.8)	(2.1)	(2.1)	(2.7)	(3.0)	(2.9)	(2.9)	(3.4)
237		EP100, 100B Sound Silencer	P2	VI	C		27	29	31	33	37	43	45	40	36
							(3.9)	(2.9)	(3.0)	(3.0)	(4.0)	(3.4)	(3.6)	(4.2)	(4.3)
238		EP200, 201 Sound Less	PE	FO	C		24	30	37	40	40	46	46	44	41
							(2.7)	(4.7)	(4.8)	(3.0)	(3.6)	(3.7)	(5.2)	(6.0)	(4.0)
239		20 Sound Ban Behind-the-Head	CS	VI	B	1	28	25	21	22	35	46	48	47	45
						(11)	(3.5)	(3.2)	(2.8)	(2.6)	(2.5)	(2.6)	(4.2)	(4.1)	(3.7)
240		20 Sound Ban Under-the-Chin	CS	VI	B	1	25	24	22	24	36	46	47	48	46
						(10)	(2.6)	(2.1)	(2.0)	(1.8)	(2.4)	(2.5)	(3.5)	(4.7)	(3.9)
241		10 Sound Ban Over-the-Head	CS	VI	B	2	24	21	19	22	40	50	49	44	42
						(9)	(3.7)	(2.4)	(3.1)	(2.5)	(4.9)	(3.0)	(3.7)	(5.9)	(6.0)
242		10 Sound Ban Behind-the Head	CS	VI	B	2	26	22	19	22	40	49	48	43	42
						(10)	(4.2)	(3.1)	(2.3)	(2.8)	(4.2)	(3.2)	(4.3)	(5.3)	(6.0)
243		10 Sound Ban Under-the-Chin	CS	VI	B	2	27	22	17	21	39	48	45	43	42
						(10)	(4.5)	(4.2)	(2.5)	(1.7)	(3.0)	(3.0)	(3.4)	(7.1)	(5.0)

Appendix II. Values of "Q" and "NRR" for Hearing Protection Devices in Appendix I.

I.D. No.	Type	Q1	Q2	Q3	Q4	Q5	Q6	Q7	NRR
1	Plug	32.3	26.6	23.0	25.2	29.8	30.8	31.9	24
2	Plug	32.9	28.6	26.0	28.4	30.2	34.7	34.8	26
3	Muff	24.7	23.6	21.6	26.8	25.4	23.2	28.1	21
4	Muff	25.5	21.8	24.6	27.8	30.0	34.3	33.5	23
5	Muff	19.3	18.2	17.4	22.6	29.2	29.3	26.5	17
6	Plug	22.1	19.6	16.6	16.2	24.2	27.4	26.8	16
7	Muff	29.9	26.2	27.0	34.8	31.8	31.5	38.3	26
8	Muff	24.7	22.4	25.0	31.6	31.6	30.8	33.9	23
9	Muff	26.5	23.8	24.8	29.4	34.0	31.3	35.1	24
10	Muff	30.3	28.4	25.2	31.6	31.4	36.2	37.1	26
11	Muff	24.9	24.6	22.2	27.0	29.4	35.0	32.6	23
12	Muff	21.9	21.2	19.4	23.8	25.4	34.8	30.0	20
13	Muff	24.3	23.0	20.8	29.8	26.2	34.1	30.8	22
14	Muff	27.1	21.6	22.2	28.0	29.2	37.3	35.2	22
15	Muff	24.9	18.2	19.8	28.0	28.4	34.3	34.3	20
16	Muff	22.9	19.4	19.4	27.0	26.0	35.3	33.2	20
17	Muff	21.7	17.2	18.4	23.2	23.8	31.7	31.2	18
18	Muff	28.5	22.6	21.0	25.0	26.0	34.5	37.3	22
19	Plug	22.1	19.6	16.6	16.2	24.2	27.4	26.8	16
20	Plug	28.9	23.2	16.8	20.4	23.0	25.2	28.5	18
21	Muff	27.5	25.2	26.0	28.2	30.6	33.0	36.0	25
22	Muff	19.3	19.2	18.2	22.0	29.8	30.4	32.6	18
23	Muff	20.5	20.0	21.8	27.4	30.0	32.4	32.4	20
24	Muff	18.5	17.0	16.8	21.0	26.4	27.9	32.3	17
25	Muff	24.1	18.6	23.8	30.4	33.8	31.4	31.3	21
26	Plug	27.3	20.0	16.8	19.6	24.4	28.5	24.2	18
27	Plug	30.9	22.0	15.6	19.2	23.2	25.3	23.3	17
28	Plug	30.7	23.4	16.0	19.0	22.0	25.3	23.1	17
29	Plug	36.3	28.8	22.4	25.2	30.2	31.0	29.1	24
30	Plug	31.7	27.2	23.6	25.4	29.8	32.7	33.5	24
31	Muff	-	-	-	-	-	-	-	-
32	Plug	15.5	8.8	11.8	14.8	21.8	29.8	23.6	11
33	Plug	35.1	27.8	25.8	24.4	31.0	34.7	31.1	25
34	Plug	31.9	27.0	24.2	20.0	26.8	33.5	33.8	22
35	Plug	36.5	30.2	26.0	27.2	30.2	38.1	37.5	27
36	Plug	21.3	18.4	15.4	16.2	26.0	31.5	33.6	16
37	Plug	37.7	30.0	26.8	27.8	30.8	32.4	30.4	26
38	Muff	29.3	26.0	24.4	29.6	35.8	41.7	40.9	25
39	Muff	25.3	23.4	23.8	27.6	34.8	38.3	36.8	23
40	Muff	26.1	24.0	24.4	28.8	36.4	40.9	38.1	24
41	Muff	34.7	29.6	30.4	31.6	34.8	35.0	32.9	29
42	Muff	33.5	29.0	29.0	32.6	32.6	34.2	34.2	28
43	Muff	30.9	28.8	30.8	32.2	31.8	35.1	33.3	28
44	Muff	28.9	25.8	23.2	32.4	33.2	36.5	34.2	25
45	Muff	27.9	22.8	23.4	29.6	33.0	35.5	34.1	24
46	Muff	26.3	22.2	23.4	30.4	32.4	33.6	32.6	23
47	Muff	24.5	22.6	23.2	29.0	27.8	34.8	35.1	22
48	Muff	27.5	25.6	25.2	31.4	31.8	33.7	34.3	25
49	Muff	27.3	20.6	20.4	24.2	31.0	37.9	34.5	21
50	Muff	23.7	15.8	17.6	27.4	30.0	35.4	38.0	18
51	Muff	26.7	21.8	20.2	28.6	33.2	33.7	32.0	22
52	Muff	25.7	22.2	19.8	26.2	32.2	34.4	32.5	21
53	Muff	26.1	22.6	23.2	26.0	30.2	35.0	33.2	23
54	Plug	31.7	27.2	23.6	25.4	29.8	32.7	33.5	24
55	Plug	33.9	29.6	27.0	29.4	31.2	35.7	35.8	27
56	Muff	31.5	27.6	21.8	23.6	23.2	24.6	27.9	21
57	Muff	24.3	24.4	25.0	27.8	32.0	32.6	33.3	23
58	Muff	21.9	23.4	24.8	32.4	31.4	30.8	32.0	23
59	Muff	27.1	22.8	21.0	23.8	26.0	25.5	27.8	21
60	Muff	23.1	19.6	24.0	23.8	24.8	27.0	25.1	20

I.D. No.	Type	Q1	Q2	Q3	Q4	Q5	Q6	Q7	NRR
61	Muff	24.7	25.2	25.0	31.4	34.6	37.1	34.9	24
62	Muff	19.9	19.0	21.6	27.6	31.6	34.8	35.0	20
63	Muff	20.5	19.2	23.0	28.8	32.0	34.7	33.8	20
64	Muff	23.7	22.0	23.4	26.0	28.2	28.5	27.7	21
65	Muff	22.9	23.2	22.2	26.2	27.0	30.0	28.7	21
66	Muff	21.5	20.4	20.6	22.2	23.6	27.9	23.8	19
67	Plug	46.7	39.8	38.6	35.2	30.6	35.1	34.3	32
68	Plug	31.9	25.2	21.6	23.2	25.2	55.1	32.4	22
69	Plug	30.9	24.6	21.6	22.6	25.6	30.7	31.7	22
70	Muff	30.3	27.0	26.6	30.2	29.8	31.3	34.1	26
71	Muff	22.7	24.2	25.6	35.2	35.2	31.2	34.3	24
72	Muff	29.1	23.6	29.0	34.4	31.0	29.1	31.6	25
73	Plug	44.3	40.6	39.6	33.6	30.2	36.2	36.6	32
74	Plug	32.1	26.6	23.2	24.0	28.8	29.5	32.1	23
75	Plug	22.1	19.6	16.6	16.2	24.2	27.4	26.8	16
76	Muff	29.1	23.6	28.0	34.4	31.0	29.1	31.6	25
77	Muff	24.5	17.8	20.2	25.4	28.6	29.5	26.2	19
78	Plug	35.9	29.8	24.0	25.8	29.4	33.3	30.4	25
79	Plug	21.3	18.4	15.4	16.2	26.0	31.5	33.6	16
80	Plug	34.9	30.2	26.6	26.2	30.8	37.6	30.9	26
81	Plug	33.7	28.0	25.0	27.4	29.2	31.2	29.1	25
82	Plug	31.7	27.2	23.6	25.4	29.8	33.2	33.5	24
83	Plug	33.9	29.6	27.0	29.4	31.2	35.7	35.8	27
84	Plug	22.1	19.6	16.6	16.2	24.2	27.4	26.8	16
85	Plug	27.3	20.0	16.8	19.6	24.4	28.5	24.2	18
86	Plug	30.7	23.4	16.0	19.0	22.0	25.3	24.1	17
87	Plug	30.9	22.0	15.6	19.2	23.2	25.3	23.3	17
88	Muff	28.5	25.8	26.4	34.0	32.2	35.7	33.9	26
89	Muff	27.3	24.2	24.4	30.0	30.2	37.0	31.2	24
90	Muff	25.5	24.4	23.8	31.0	29.8	35.2	31.1	24
91	Muff	25.1	21.6	20.6	26.0	28.8	34.8	31.8	21
92	Muff	29.1	23.6	28.0	34.4	31.0	29.1	31.6	25
93	Muff	21.1	17.4	14.8	21.6	23.6	28.7	33.2	16
94	Muff	20.3	17.2	15.4	20.6	24.0	24.8	33.2	16
95	Muff	26.7	21.8	23.4	31.0	33.0	36.1	34.5	23
96	Muff	25.5	20.8	22.0	28.6	30.2	32.6	33.3	22
97	Muff	26.7	22.0	21.4	27.2	32.0	36.3	33.3	22
98	Muff	19.9	16.8	22.2	29.4	29.8	33.9	34.1	19
99	Muff	21.5	17.8	22.2	27.4	30.0	33.0	34.2	20
100	Muff	21.7	19.0	23.2	29.4	28.2	32.3	32.6	20
101	Muff	17.5	13.4	15.8	21.0	22.8	19.4	22.7	14
102	Plug	41.5	36.8	33.4	31.2	32.8	37.0	38.0	31
103	Plug	31.5	21.8	15.4	17.4	24.6	26.7	21.2	17
104	Plug	18.9	10.0	8.2	10.6	20.4	20.3	11.8	9
105	Plug	35.9	30.2	28.2	28.0	28.4	35.5	34.0	27
106	Plug	39.9	32.0	29.8	26.8	24.2	31.6	35.9	26
107	Plug	32.1	25.8	24.0	26.6	32.2	36.2	37.2	25
108	Plug	31.9	24.6	22.8	25.8	31.6	32.9	33.9	24
109	Plug	22.5	18.2	20.8	25.8	29.2	36.5	28.5	20
110	Plug	39.5	33.6	34.4	33.8	32.2	38.5	32.6	31
111	Plug	30.1	26.0	19.2	16.2	33.8	32.8	33.6	19
112	Plug	31.7	27.2	23.6	25.4	29.8	32.7	33.5	24
113	Plug	33.9	29.6	27.0	29.4	31.2	35.7	35.8	27
114	Plug	45.1	39.4	36.6	33.6	32.8	35.8	37.9	32
115	Muff	29.5	24.4	23.6	29.2	31.6	31.4	30.0	24
116	Muff	23.3	17.6	22.8	26.6	27.8	28.5	24.3	19
117	Muff	21.7	17.0	19.8	26.8	27.8	27.9	23.3	18
118	Plug	34.9	27.8	20.6	24.2	26.6	29.9	24.8	22
119	Plug	38.1	31.2	27.8	29.2	28.8	29.9	30.7	26
120	Plug	39.5	32.2	26.6	28.2	31.0	33.3	30.3	27

I.D. No.	Type	Q1	Q2	Q3	Q4	Q5	Q6	Q7	NRR
121	Muff	22.3	21.0	20.0	21.4	25.6	30.4	27.8	19
122	Muff	22.9	18.2	19.6	19.6	24.8	27.6	25.6	18
123	Muff	21.9	18.4	20.2	19.2	24.6	29.9	27.0	18
124	Muff	26.7	26.0	28.2	31.8	31.6	31.7	32.3	25
125	Muff	25.7	24.8	27.4	30.6	30.4	33.0	34.6	25
126	Muff	26.7	26.6	23.6	26.6	31.4	38.0	35.2	24
127	Muff	27.1	24.4	22.8	27.6	29.2	36.8	34.1	23
128	Muff	26.5	26.4	27.4	33.4	35.8	35.0	37.6	26
129	Muff	21.5	19.6	23.6	28.8	30.8	32.6	35.4	21
130	Muff	18.5	19.0	24.0	29.6	31.4	33.5	33.3	20
131	Muff	25.7	23.4	26.6	35.0	35.4	37.3	36.8	25
132	Muff	25.9	25.6	27.4	30.0	27.6	27.6	27.9	24
133	Muff	27.7	28.6	29.6	33.8	31.2	33.0	31.8	27
134	Muff	28.1	25.4	28.6	33.0	31.2	32.7	31.3	26
135	Muff	28.3	26.4	30.0	31.8	32.4	32.2	32.0	26
136	Muff	24.3	26.8	27.2	31.8	31.6	33.6	31.4	25
137	Muff	25.3	27.8	29.0	33.6	31.6	34.1	31.6	26
138	Muff	28.3	27.6	28.6	32.2	30.4	32.4	32.0	26
139	Muff	24.9	26.6	27.6	29.6	27.2	28.8	25.3	23
140	Muff	26.9	24.4	26.4	31.8	28.6	33.5	33.6	25
141	Muff	24.1	21.2	22.8	28.0	29.0	30.9	27.1	21
142	Plug	44.3	40.6	39.6	33.6	30.2	36.2	34.6	31
143	Muff	25.9	23.6	25.2	31.8	30.4	31.1	32.1	24
144	Muff	23.1	21.8	24.6	31.4	30.8	30.3	27.9	22
145	Muff	21.5	18.8	20.8	27.6	28.4	30.4	26.7	19
146	Muff	23.5	22.4	24.0	31.8	29.8	29.3	26.8	22
147	Muff	24.7	23.0	22.8	30.6	29.6	30.8	26.8	22
148	Muff	24.3	17.2	23.0	27.0	27.4	34.3	33.9	20
149	Muff	24.9	18.8	23.4	27.6	29.2	36.5	33.1	21
150	Muff	22.9	18.8	23.4	26.2	28.2	34.1	31.6	20
151	Muff	20.9	18.6	20.4	24.8	26.8	35.7	31.1	19
152	Muff	27.5	29.0	29.4	33.6	34.6	35.2	31.9	27
153	Muff	26.3	19.2	23.8	28.0	31.2	34.3	31.0	21
154	Muff	26.3	19.2	23.8	28.0	31.2	34.3	31.0	21
155	Muff	24.9	16.8	23.4	27.6	29.2	36.5	33.1	21
156	Muff	27.5	29.0	29.4	33.6	34.6	35.2	31.9	27
157	Plug	31.7	27.2	23.6	25.4	29.8	32.7	33.5	24
158	Plug	33.9	29.6	27.0	29.4	31.2	35.7	35.8	27
159	Plug	45.1	39.4	36.6	33.6	32.8	35.8	37.9	32
160	Muff	24.3	24.4	25.0	27.8	32.0	32.6	33.3	23
161	Muff	23.1	19.6	24.0	23.8	24.8	27.0	25.1	20
162	Muff	21.9	23.4	24.8	32.4	31.4	30.8	32.0	23
163	Plug	34.9	30.2	26.6	26.2	30.8	37.6	30.9	26
164	Plug	22.1	19.6	16.6	19.2	24.2	30.9	30.3	17
165	Muff	22.7	24.2	25.6	35.2	35.2	31.2	34.3	24
166	Muff	22.9	23.0	24.2	31.4	32.4	32.0	32.9	23
167	Muff	22.3	22.8	26.0	32.0	34.0	31.9	31.6	23
168	Plug	33.9	29.6	27.0	29.4	31.2	35.7	35.8	27
169	Muff	22.7	17.0	16.8	22.6	25.6	28.0	24.4	17
170	Muff	22.3	20.6	22.0	27.8	30.6	32.5	27.7	21
171	Muff	28.5	23.4	23.4	28.2	31.6	33.9	30.7	23
172	Muff	24.7	20.8	21.2	31.4	32.8	31.5	28.2	21
173	Muff	26.9	23.6	22.2	28.0	28.6	28.7	28.1	22
174	Muff	32.3	31.2	32.4	37.0	36.0	34.7	31.0	29
175	Muff	24.1	23.8	26.8	30.4	27.8	33.4	30.0	23
176	Muff	28.5	26.6	24.8	31.4	32.0	34.4	32.8	25
177	Muff	28.9	24.0	25.0	31.4	33.4	34.4	32.4	25
178	Muff	24.3	22.8	24.6	30.2	31.6	32.5	31.4	23
179	Muff	31.5	29.6	29.6	33.6	35.0	33.4	32.7	28
180	Muff	24.5	20.6	22.2	24.6	27.8	29.3	31.9	21
181	Muff	27.9	22.0	25.6	27.8	30.8	32.3	31.9	23
182	Plug	35.3	21.8	28.2	27.0	27.8	36.0	30.6	24
183	Muff	23.1	19.8	24.2	28.8	27.8	36.1	32.7	21
184	Plug	40.1	30.0	26.2	27.6	28.8	33.4	38.0	26
185	Plug	28.5	27.6	26.4	26.8	30.8	37.9	39.2	26
186	Plug	21.5	19.0	14.6	16.2	23.0	28.2	24.2	15
187	Plug	18.1	8.6	3.4	8.4	16.2	16.0	20.5	6
188	Plug	27.3	27.4	27.2	26.4	31.4	37.5	38.2	25
189	Plug	29.9	27.0	25.6	26.8	32.2	36.8	35.5	25
190	Plug	29.3	27.2	24.8	26.0	31.8	36.6	36.7	25
191	Muff	23.9	26.2	30.2	35.2	29.8	28.0	33.6	25
192	Muff	24.1	24.2	29.4	32.2	27.0	27.2	25.8	23
193	Muff	26.5	26.6	27.2	32.0	27.0	25.9	30.9	24
194	Muff	26.9	24.8	27.6	35.0	35.8	35.1	33.6	26
195	Muff	24.7	22.4	23.2	32.0	33.2	33.7	35.7	23
196	Muff	24.1	22.4	25.4	30.6	31.4	33.0	33.8	23
197	Muff	22.5	21.0	23.0	29.8	31.8	33.5	33.5	22
198	Muff	22.1	22.2	23.8	31.0	31.4	31.9	30.8	22
199	Muff	22.9	21.0	21.8	29.8	31.4	30.5	32.0	21
200	Muff	22.7	24.2	25.6	35.2	35.2	31.2	35.3	24
201	Muff	22.9	23.0	24.2	31.4	32.4	32.0	32.9	23
202	Muff	22.3	22.8	26.0	32.0	34.0	31.9	31.6	23
203	Plug	22.1	19.6	16.6	16.2	24.2	27.4	26.8	16
204	Plug	27.3	20.0	16.8	19.6	24.4	28.5	24.2	18
205	Plug	30.7	23.4	16.0	19.0	22.0	25.3	23.1	17
206	Plug	30.9	22.0	15.6	19.2	23.2	25.3	23.3	17
207	Muff	19.3	18.2	17.4	22.6	29.2	29.3	26.5	17
208	Muff	19.3	17.8	15.0	18.0	20.0	20.8	19.5	15
209	Plug	36.3	28.8	32.4	25.2	30.2	31.0	29.1	26
210	Plug	32.1	26.6	23.2	24.0	28.8	29.5	32.1	23
211	Muff	20.3	21.2	22.6	29.0	30.0	28.9	30.7	21
212	Plug	32.9	28.6	26.0	28.4	30.2	34.7	34.8	26
213	Muff	21.7	23.2	20.6	28.8	26.2	29.6	30.7	21
214	Muff	27.5	25.0	21.8	28.6	25.8	24.8	29.4	22
215	Muff	29.5	26.6	21.0	29.2	28.2	27.7	31.0	23
216	Muff	27.3	22.0	20.2	28.6	27.6	24.0	26.3	21
217	Muff	30.3	26.6	19.6	29.0	29.2	28.0	30.8	22
218	Muff	22.3	22.2	24.2	30.6	29.2	28.7	30.4	22
219	Muff	27.1	22.6	24.8	31.2	32.8	29.2	31.3	23
220	Muff	24.7	20.4	25.4	31.0	32.6	33.3	37.7	23
221	Muff	24.1	20.6	23.4	26.2	31.4	32.4	36.1	22
222	Muff	23.5	19.8	20.8	26.2	30.6	31.2	33.0	20
223	Muff	22.3	18.0	19.2	26.4	28.0	31.9	37.4	19
224	Muff	21.7	19.0	19.8	24.6	29.0	32.1	34.9	19
225	Muff	20.9	17.6	19.6	25.0	29.6	31.0	33.0	19
226	Muff	34.1	25.2	26.4	32.4	33.8	33.7	36.9	26
227	Muff	27.1	28.0	27.6	31.6	32.0	32.6	35.8	26
228	Muff	29.1	24.4	28.6	28.4	31.4	31.2	35.4	25
229	Muff	29.3	23.6	26.0	32.2	33.8	33.2	35.7	25
230	Muff	24.7	22.0	26.0	28.8	31.6	31.5	35.5	23
231	Muff	24.3	20.8	22.2	27.4	31.0	31.3	35.2	22
232	Muff	26.3	21.6	22.2	30.8	27.2	27.7	26.8	22
233	Muff	26.9	25.0	24.0	28.8	29.8	27.7	25.4	23
234	Muff	22.7	19.2	21.4	27.0	27.8	29.0	20.6	19
235	Muff	21.9	20.4	20.0	26.8	29.0	32.6	27.7	20
236	Muff	26.5	23.0	24.0	28.8	30.4	31.6	28.8	23
237	Plug	35.3	31.8	28.2	27.0	27.8	36.0	30.6	26
238	Plug	34.7	29.2	30.6	34.0	31.6	36.1	33.6	29
239	Plug	37.1	27.2	18.6	16.8	28.8	39.2	39.3	19
240	Plug	35.9	28.4	21.2	20.4	30.0	39.5	39.5	22
241	Plug	32.7	24.8	16.0	17.0	29.0	41.8	32.2	18
242	Plug	33.7	24.4	17.6	16.4	30.4	40.0	32.3	18
243	Plug	34.1	22.2	15.2	17.6	31.8	39.1	31.5	17

Real-ear attenuation of earmuffs in normal-hearing and hearing-impaired individuals

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Many of the 9 million workers exposed to average noise levels of 85 dB(A) and above are required to wear hearing protection devices, and many of these workers have already developed noise-induced hearing impairments. There is some evidence in the literature that hearing-impaired users may not receive as much attenuation from hearing protectors as normal-hearing users. This study assessed real-ear attenuation at threshold for ten normal-hearing and ten hearing-impaired subjects using a set of David Clark 10A earmuffs. Testing procedures followed the specifications of ANSI S12.6-1984. The results showed that the hearing-impaired subjects received slightly more attenuation than the normal-hearing subjects at all frequencies, but these differences were not statistically significant. These results provide additional support to the finding that hearing protection devices are capable of providing as much attenuation to hearing-impaired users as they do to normal-hearing individuals.

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INTRODUCTION

Approximately 9 million American workers are exposed to noise with daily average levels of 85 dB(A) and above (EPA, 1981), of whom more than 5 million work in manufacturing and utilities (OSHA, 1981). The Occupational Safety and Health Administration (OSHA) estimates about 1 million workers in manufacturing and utilities have noise-induced hearing impairments that exceed OSHA's definition of material impairment of hearing: an average hearing level of 25 dB or greater at 1000, 2000, and 3000 Hz (OSHA, 1981).

Since the promulgation of the OSHA noise standard in 1971, some 2.9 million workers in manufacturing and utilities, who are exposed to average noise levels of 90 dB(A) or greater, have been required to wear hearing protection devices. Many other workers in industries such as mining, construction, and transportation are covered by similar rules. In addition, military personnel and many civilian workers exposed to noise between 85 and 90 dB(A) are now required to wear hearing protectors, or choose to do so voluntarily. It is reasonable to assume, therefore, that a large portion of the more than 1 million industrial workers with hearing impairments wear hearing protection devices.

Consequently, the question could arise as to whether hearing-impaired individuals receive the same attenuation from hearing protectors as their normal-hearing counterparts. The ANSI standard S12.6-1984 for measuring hearing protector attenuation requires the use of subjects with normal hearing. Studies employing suprathreshold techniques with normal listeners, such as masking and loudness balance techniques, and a study of hearing protector linearity in cadaver ears (Martin, 1977) indicate an absence of level-dependent effects for a variety of hearing protection devices (see discussion in Berger, 1986). But whether or not the attenuation realized by normal-hearing subjects applies to hearing-impaired subjects has been open to question.

In 1979, Thunder and Lankford tested hearing protector attenuation at threshold in five normal-hearing subjects and five with flat, sensorineural hearing losses. They used a premolded, triple-flanged earplug, and a supervised subject-fit procedure, "basically" according to procedures outlined in the ANSI standard current at the time (ANSI S3.19-1974). The results showed that hearing-impaired subjects received significantly less real-ear attenuation at threshold than individuals with normal hearing (Thunder and Lankford, 1979). If these results reflect actual conditions in hearing-impaired industrial workers, the situation merits some concern.

A study of Abel *et al.* (1982) produced slightly different results. The purpose of the study was mainly to examine the effects of various factors on subjects' abilities to recognize speech with and without hearing protectors. These factors included noise level and spectrum, attenuation characteristics of hearing protectors, subject age, and fluency in English. Although it was not the primary intent of the study, the investigators did compare the attenuation realized by hearing-impaired subjects to that of normal-hearing listeners using three hearing protectors, one of which was an earmuff. They measured hearing threshold levels for 10 one-third octave bands of noise with and without hearing protectors, which were fitted by the experimenters. Abel and her colleagues report that pairwise comparisons using t tests indicated that one subgroup of subjects with high-frequency hearing losses ($N = 24$) showed significantly less attenuation than the normal-hearing group ($p < 0.05$) in one particular frequency range (3000–6000 Hz). No mention is made of the other subjects with high-frequency hearing loss or the other frequencies, where, presumably, no significant differences were found. Subjects with flat losses ($N = 24$)

showed significantly more attenuation ($p < 0.05$) than normal-hearing subjects in a slightly different frequency range (2000–4000 Hz), with no significant differences at the other frequencies. Actual data are not shown, and the graphic representations are difficult to read, but it appears that the differences are not systematic in terms of frequency or direction of effect. The authors give no explanation of these differences.

A few years later, Berger (1985) reported the results of an experiment in which hearing threshold level was correlated with real-ear attenuation at threshold for an expandable foam earplug. Using seven subjects with losses at 3000 Hz and above (hearing threshold levels of 30 dB or greater), Berger found no significant correlation between hearing threshold level and attenuation at threshold. In fact, the mean attenuation at 3150–8000 Hz was virtually the same for the hearing-impaired and normal-hearing subjects.

The present study represents another attempt to examine the possibility of differences between hearing-impaired and normal-hearing listeners with respect to real-ear attenuation at threshold, this time using earmuffs instead of earplugs, and a slightly larger subject pool than that used by Berger or Thunder and Lankford. Although the subject population in the present study was not quite as large as that used by Abel *et al.* (1982), it appeared that another investigation into this issue was indicated. The null hypothesis was: There is no difference in the measured attenuation of an earmuff hearing protector when worn by normal-hearing and hearing-impaired listeners.

I. METHOD

Subjects consisted of 20 men between the ages of 20 and 55 years. Ten had hearing threshold levels of 15 dB or better at the audiometric frequencies 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz, with the exception of two subjects who exceeded this criterion by 5 dB at one frequency each. The other ten subjects had mild-to-moderate sensorineural hearing losses. Mean hearing threshold levels, standard deviations, and ranges for the two groups are displayed in Fig. 1(a) and (b). Subjects with hearing losses were regularly exposed to noise on the job and were in the habit of wearing hearing protectors for most of the workshift. Most of those with normal hearing also wore hearing protectors daily at work (six out of ten subjects), but the remaining subjects wore hearing protectors infrequently, if at all.

The following criteria were applied to all subjects: (1) differences between left- and right-ear air-conduction thresholds for the same frequency were no greater than 15 dB, except that deviations of up to 5 dB were allowed at one frequency; (2) differences between air-conduction and bone-conduction thresholds for each frequency were never greater than 10 dB; (3) no subject had a history of recent middle-ear disease; (4) all subjects showed normal tympanograms and auditory reflexes; and (5) all subjects displayed trace widths for fixed-frequency Bekesy audiometry greater than 3 dB and less than 13 dB on the initial audiogram.

The tests were conducted in a semi-reverberant sound room meeting the specifications of ANSI S12.6-1984, with three loudspeakers positioned to create a quasi-diffuse sound

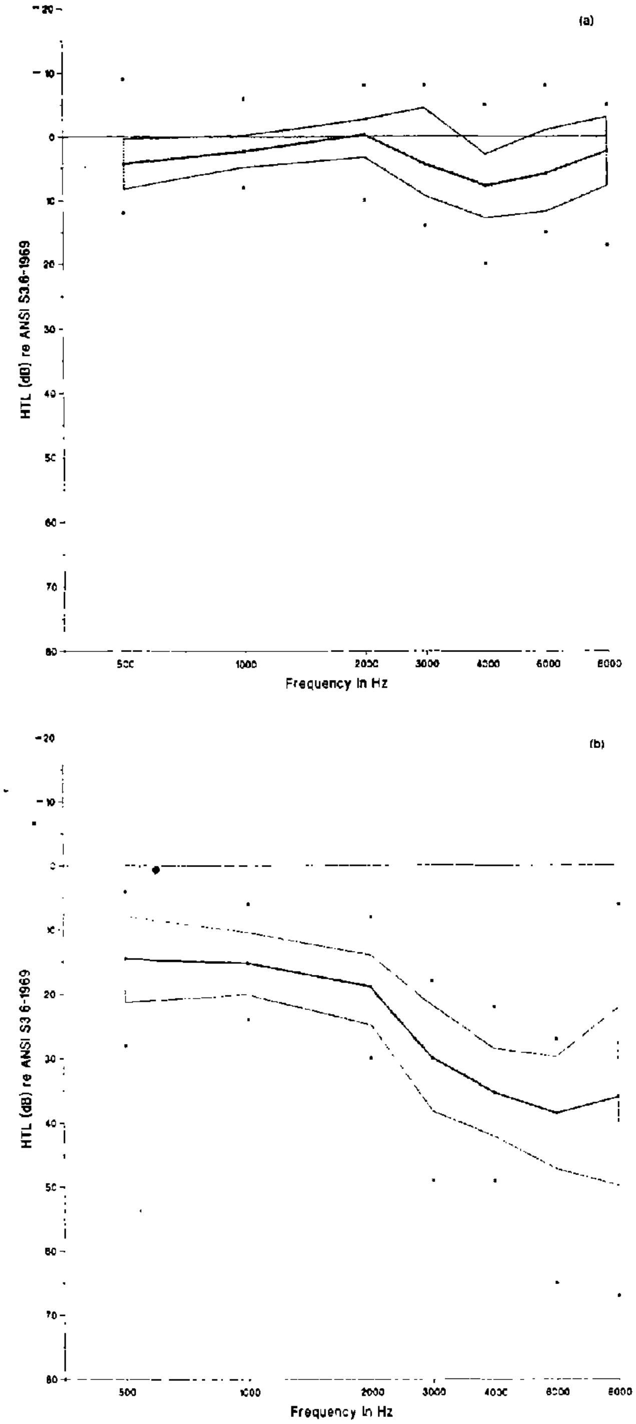

FIG. 1. Mean hearing threshold levels, standard deviations (shaded area), and ranges (dots). (a) For the normal-hearing group and (b) for the hearing-impaired group.

field. Ambient noise levels were lower than those required by ANSI S12.6 by at least 4 dB (see Table I). Ears were occluded with a David Clark model 10A earmuff, which was fitted by the experimenter. Subjects were allowed to readjust the earmuffs, although they were not given a "fitting noise" to use for this purpose, after which the experimenter inspected the fit to make sure that the muffs were positioned properly. Subjects were advised not to move their heads, and a plumb bob was arranged to facilitate this centering. They

TABLE I. Background sound levels in test room.

Octave band center frequency in Hz	Background sound-pressure level in dB	ANSI S12.6-1984 requirements
125	21	28
250	12	18
500	7	14
1000	4	14
2000	4	8
4000	5	9
8000	7	20

were then told not to touch or readjust their earmuffs.

Pink noise was generated by a General Radio 1382 random noise generator, filtered into one-third octave bands by a Hewlett–Packard 8056A filter set, and presented through a Grason–Stadler model 1701 audiometer.

Signals were presented for the one-third octave bands centered at 125, 250, 500, 1000, 2000, 3150, 4000, 6300, and 8000 Hz. Hearing threshold levels were obtained first for the unoccluded condition, followed by the occluded condition. This procedure was followed three times for each subject, with rest periods of 10 to 15 min between each measurement session. The results were scored by drawing a horizontal line parallel to the time axis at the apparent midpoint of the tracing's envelope for each frequency. Real-ear attenuation at threshold was taken to be the hearing threshold level in the occluded minus the unoccluded conditions for each frequency. One observation consisted of the mean attenuation of the three sessions for each of the ten subjects in each group, at each of the nine frequencies. Although ANSI S12.6-1984 specifies calculating the difference between occluded and unoccluded measurements for all three tests for each subject, we concluded that a more appropriate procedure for this experiment would be to average the results of the three tests at each frequency. Because the data from the three sessions were derived from the same subject, they could not be considered independent. Multivariate comparisons between the two groups were then computed using the Hotelling T^2 statistic (Johnson and Wichern, 1988).

II. RESULTS

Both groups received slightly less than ideal attenuation, represented by the manufacturer's specifications, particularly in the low frequencies. These results are displayed in Table II and Fig. 2, which show that the mean attenuation received by the hearing-impaired subjects is slightly greater than that received by the normal-hearing subjects at all frequencies. The multivariate comparisons based on the T^2 statistic showed that the difference between groups was not statistically significant ($F = 0.779$; $df = 9,10$, p value $= 0.641$). Thus we could not reject the null hypothesis.

III. DISCUSSION

The effect of hearing threshold level on hearing protector attenuation found in this study is not in agreement with the results of Thunder and Lankford (1979). In fact, the small differences that did appear are in the opposite direction of the effect found by Thunder and Lankford. One reason for the discrepancy could be that some of Thunder and Lankford's subjects had severe hearing losses, which, when coupled with earplug attenuation, could have surpassed the capabilities of the signal-generating system.

With respect to the study by Abel *et al.* (1982), one group of hearing-impaired subjects from that investigation did show significantly higher earmuff attenuation values at three frequencies than those achieved by the normal listeners, but the other group showed the opposite effect. Berger (1986) suggests that the reason why the group with high-frequency impairments received less measured attenuation was due to possible bandwidth and frequency response limitations in the investigators' signal generation and presentation equipment, which enabled subjects to respond to sound energy at frequencies lower than the test frequencies. It is not clear why those with flat losses achieved significantly better attenuation at certain frequencies than the normal-hearing subjects.

The results of the present study are in general agreement with those of Berger (1985). The apparent differences between means in this study, although they are systematic, are not statistically significant. Even these small differences, should they prove to be significant with a much larger subject population, are not likely to have been caused either by truncation effects due to limitations in the equipment, or by

TABLE II. Mean attenuation and standard deviations in dB for normal-hearing and hearing-impaired groups.

	One-third octave band center frequency in Hz								
	125	250	500	1000	2000	3150	4000	6300	8000
Normal-hearing subjects ($N = 10$)									
Mean	5.9	9.4	19.2	27.4	31.3	28.6	30.3	31.2	30.9
s.d.	4.8	5.6	5.7	4.6	4.3	4.9	4.6	7.4	6.7
Hearing-impaired subjects ($N = 10$)									
Mean	8.2	13.6	23.3	31.3	34.7	33.2	34.8	32.6	34.4
s.d.	4.5	4.4	4.2	5.3	3.8	2.6	3.3	2.5	5.0

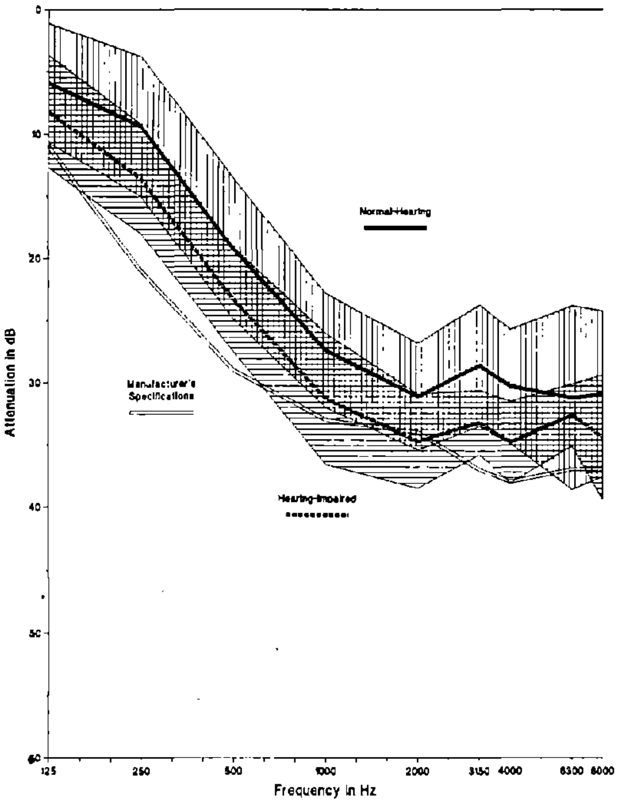

FIG. 2. Real-ear attenuation at threshold for the David Clark 10A earmuff: Mean values for normal-hearing and hearing-impaired groups, with standard deviations represented by shaded areas. Vertical hatching represents the normal-hearing group, and horizontal hatching represents the hearing-impaired group. Also shown are the manufacturer's specifications.

masking noise in the test room. Audiometric tracings show no signs of dwelling at the limits of the audiometer, and the background levels in the test room were more stringent than those specified by ANSI S12.6-1984 by 4 dB to as much as 13 dB. If the small differences between groups are indeed real, it may have to do with the fact that the hearing-impaired group was somewhat more experienced in the use of hearing protection. This explanation is only speculative, and perhaps unnecessary, since, after all, the differences were not statistically significant.

IV. CONCLUSIONS

The results of this experiment provide additional support to the finding that hearing protection devices are capable of providing at least as much attenuation to hearing-impaired wearers as they do to individuals with normal hearing. To the extent that these results represent the hearing-impaired workforce, concerns about this issue raised elsewhere in the literature appear to be unfounded.

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