AMERICAN SPEECH-LANGUAGE-HEARING ASSOCIATION

COMBATTING NOISE IN THE '90s:

A NATIONAL STRATEGY FOR THE UNITED STATES

SYMPOSIUM FINAL REPORT AND RECOMMENDATIONS FROM THE PROFESSIONAL COMMUNITY TO THE 102nd CONGRESS

ON THE OCCASION OF THE
20th ANNIVERSARY OF THE
NOISE CONTROL ACT

American Speech-Language-Hearing Association
National Office • Rockville, Maryland
December 17, 1991

Cosponsored by
Acoustical Society of America
American Academy of Otolaryngology - Head and Neck Surgery

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SPEECH-LANGUAGE-
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SYMPOSIUM FINAL REPORT

Evelyn Cherow, M.A.
Director, Audiology Division
American Speech-Language-Hearing Association
Editor

The final report, *Combatting Noise in the '90s: A National Strategy for the United States,* was published by the American Speech-Language-Hearing Association in cooperation with the American Academy of Otolaryngology - Head and Neck Surgery. For additional single copies contact:

Fulfillment Operations
American Speech-Language-Hearing Association
10801 Rockville Pike
Rockville, MD 20854
(301) 897-5700 ext. 218.

This report is printed on recycled paper using soybean oil inks.

"Our research findings clearly support the need to take definitive action to control noise in the U.S., but even without further research, we should move forward, if for no other reason than to preserve our tranquillity ... a resource unmeasurable but of clear value to our health and welfare..."

Symposium participant
December 17, 1991

TABLE OF CONTENTS

ACKNOWLEDGMENTS

The symposium **"Combatting Noise in the '90s: A National Strategy for the United States"** was initiated by Congressman Richard J. Durbin of Illinois and funded by the American Speech-Language-Hearing Association in cooperation with co-sponsoring organizations, the Acoustical Society of America and the American Academy of Otolaryngology - Head and Neck Surgery.

Representatives Richard J. Durbin (D - IL) and Patricia Schroeder (D - CO), member and Chair respectively, of the House Select Committee on Children, Youth, and Families, were responsible for Congressional hearings held in July of 1991 during which audiologists, hearing scientists, otolaryngologists, and consumers spoke of the deleterious environmental and occupational noise pollution effects upon the quality of life of our nation's children and adults. The testimony and written comments inspired Rep. Durbin to request a report from experts on noise to answer two questions: (a) What should be the federal government's noise policy? and (b) What legislative strategy should be used to implement this policy? Our gratitude is extended to Representatives Durbin and Schroeder for understanding the serious consequences of noise exposure and inviting the professional community to offer our recommendations for action.

Special recognition is offered to a dedicated planning committee, symposium working group chairs and faculty: Evelyn Cherow and Sydney Olson, Symposium Coordinators, Special Assistant, Susan Karr (whose tireless and enthusiastic management expedited our work) of the American Speech-Language-Hearing Association; Ed Heffernan, Legislative Assistant for Rep. Durbin; Elliott H. Berger, Clifford R. Bragdon, Robert D. Bruce, William W. Clark, Paul R. Lambert, Ernest A. Peterson, Julia Doswell Royster, James B. Snow, Jr., Alice H. Suter (who volunteered to wear multiple hats throughout the planning and implementation of the project, and as always, wore them all well and with great dedication), Nancy S. Timmerman, and Henning E. von Gierke. In addition, over 70 experts volunteered to participate as members of one of nine working groups. All of these individuals gave of their time, knowledge, and experience to ensure that the final product was one of quality and substance.

Special thanks are extended to the Executive Board and staff too numerous to mention of the American Speech-Language-Hearing Association for the tremendous support offered in the planning of the symposium and production of the report to Congress. Frederick T. Spahr, Executive Director, Patrick J. Carney, 1991 ASHA President, and Ann L. Carey, 1992 ASHA President, have a strong investment in the goals of this project. In particular, the teamwork extended from the Professional Practices, Public Information, and Governmental Affairs Departments, and the Component Governance and Administrative Services Division was invaluable to ensuring the symposium's success.

Charles E. Schmid, Executive Director, and Eric E. Ungar, President, Acoustical Society of America, and Jerome C. Goldstein, Executive Vice President, American Academy of Otolaryngology - Head and Neck Surgery, are recognized for their collaborative spirit and strong support.

Sharyn Schlesinger offered an attention to detail under pressure that is the mark of a professional production editor and is essential to the publication of a multi-authored report. Tarja Carter and Dorothy Valiga added the necessary creative expertise to finalize report design and production and convey the written message graphically.

Lastly, to those professionals who attended the symposium and/or offered written or verbal input to the deliberations, we offer our thanks for their thoughtful remarks.

FACULTY AND WORKING GROUP CHAIRS

Elliott H. Berger, MS
Manager, Acoustical Engineering
Cabot Safety Corporation
7911 Zionsville Road
Indianapolis, IN 46268-1657

Clifford R. Bragdon, PhD
Special Assistant, Office of the President
Professor of City Planning
Carnegie Building
Georgia Institute of Technology
Atlanta, GA 30332-0325

Robert D. Bruce, FASA, Mem INCE, EE
Principal Consultant
Collaboration in Science and Technology, Inc. (CSTI)
15835 Park Ten Place, Suite 105
Houston, TX 77084-5131

William W. Clark, PhD
Senior Research Scientist
Central Institute for the Deaf
Chair, Graduate Program in Communication Sciences
Washington University
St. Louis, MO 63110

Paul R. Lambert, MD
Professor of Otolaryngology-Head and Neck Surgery
Director of Otology-Neurotology
Department of Otolaryngology-Head and Neck Surgery
University of Virginia
Health Sciences Center, Box 430
Charlottesville, VA 22908

Karl S. Pearsons, MS
Senior Scientist
BBN Systems and Technologies
21120 Vanowen Street
Canoga Park, CA 91303

Ernest A. Peterson, PhD
Codirector, Medical Computer Systems Laboratory
MCSL (D-55)-Trailer Annex 2
University of Miami School of Medicine
1800 NW 10th Avenue
Miami, FL 33136

Julia Doswell Royster, PhD
President, Environmental Noise Consultants, Inc.
P.O. Box 30698
Raleigh, NC 27622-0698

James B. Snow, Jr., MD
Director, National Institute on Deafness and Other Communication Disorders
National Institutes of Health
Bethesda, MD 20892

Alice H. Suter, PhD
Consultant in Industrial Audiology and Community Noise
1657 River Dee Court
Cincinnati, OH 45230

Nancy S. Timmerman, SM
President, Institute of Noise Control Engineering
Noise Abatement Supervisor
MASSPORT
Logan International Airport
East Boston, MA 02128

Henning E. von Gierke, PhD
Director Emeritus
Biodynamics and Biocommunications Division
Armstrong Aerospace Medical Research Laboratory
Wright-Patterson AFB, OH 45433-6573

CONFERENCE PARTICIPANTS

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

Brenda Battat, MS
Deputy Executive Director
SHHH, Inc.
7800 Wisconsin Avenue
Bethesda, MD 20814

Karin Bierstein, JD, MPH
Director of the Office of Health Policy
American Academy of Otolaryngology - Head and Neck Surgery
One Prince Street
Alexandria, VA 22314

Patrick Brookhauser, MD
NICHD Council Representative
Director Boys Town National Research Hospital
555 North 30th Street
Omaha, NE 61831

Thomas R. Brooks
Professional Staff Member
Select Committee on Children, Youth, and Families
H2-385 Ford House Office Building
Washington, DC 20515

Ann L. Carey, PhD
1992 President
American Speech-Language-Hearing Association
Southern Illinois University
33 Estates View Drive
Fairview Heights, IL 62208

Patrick J. Carney, PhD
1991 President
American Speech-Language-Hearing Association
University of Tennessee
Department of Audiology and Speech Pathology
457 South Stadium Hall
Knoxville, TN 37996-0740

Cosimo Caccavari
Staff Assistant
Field Operations and Support Division
Office of Air and Radiation
United States Environmental Protection Agency (USEPA)
401 M Street, SW, Mail Code 397F
Washington, DC 20460

Congressman Richard J. Durbin
129 Cannon Building
Washington, DC 20515

Kenneth Feith
Senior Scientific Advisor
United States Environmental Protection Agency
ANR-443
Washington, DC 20460

Deborah Feldman, MS
Health Scientist - Audiologist
U. S. Department of Labor (OSHA)
200 Constitution Avenue, NW
Washington, DC 20210

Lawrence Finegold
Research Psychologist, USAF
AL/OEBN-NSBIT
Wright-Patterson Airforce Base, OH 45433-6573

John Franks, PhD
Physical Scientist
National Institute for Occupational Safety and Health (NIOSH)
4676 Columbia Parkway
Cincinnati, OH 45226

Jerome C. Goldstein, MD
Executive Vice President
American Academy of Otolaryngology - Head and Neck Surgery
One Prince Street
Alexandria, VA 22314

John T. Grupenhoff, PhD
President
Science and Health Communication Group
6410 Rockledge Drive, #203
Bethesda, MD 20817

Ed Heffernan
Legislative Assistant
for Congressman Richard J. Durbin
129 Cannon Building
Washington, DC 20515

Timothy Margulies, PhD
Acoustician and Risk Manager
908 Marine Drive
Annapolis, MD 21401

Fred Mintz, MS
Staff Consultant
United States Environmental Protection Agency
4601 North Park Avenue, #908
Chevy Chase, MD 20815

Donald W. Nielsen, PhD
Executive Vice President for Research
House Ear Institute
2100 W. 3rd Street
Suite 410
Los Angeles, CA 90057

Thomas J. O'Toole, EdD
Vice President for Administration
American Speech-Language-Hearing Association
Montgomery County Public Schools
217 Rolling Road
Gaithersburg, MD 20877

Richard Peppin
SCANTEK, Inc.
916 Gist Avenue
Silver Spring, MD 20910

Charles Price
Executive Director
National Organization to Insure a Sound Control Environment (NOISE)
1225 Eye Street, N.W.
Suite 300
Washington, DC 20005

David Pritzker
Senior Attorney
Administrative Conference of the United States
2120 L Street, N.W.
Suite 500
Washington, DC 20037

Frederick T. Spahr, PhD
Executive Director
American Speech-Language-Hearing Association
10801 Rockville Pike
Rockville, MD 20852

John Steelmack
Industrial Hygienist
Health Standards, OSHA
Room N3718
200 Connecticut Avenue, NW
Washington, DC 20210

Pearl G. Weissler
5510 Uppingham Street
Chevy Chase, MD 20815

Milton Whitcomb, PhD
Study Director for the Committee on Hearing, Bioacoustics and Biomechanics
National Academy of Sciences
2101 Constitution Avenue
Washington, DC 20418

Frank E. Wilcher, Jr
President
Industrial Safety Equipment Association
1901 N. Moore Street
Arlington, VA 22209

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INTRODUCTORY REMARKS: 1991 ASHA PRESIDENT

Patrick J. Carney

Welcome to Rockville and the National Office of the American Speech-Language-Hearing Association. I am Jerry Carney, President of ASHA. It is a pleasure to open this one-day symposium on **"Combatting Noise in the '90s: A National Strategy for the United States."** Some would say we have set ourselves an impossible task: How to define a workable, realistic plan for reducing the impact of noise on daily life at home, at work, and at play. And all in the space of 12 hours! I don't agree. No question about it, it's a difficult task. It is, however, a challenge that the individuals in this room are more than able to meet.

An interesting chain of events led to our meeting here today. In 1988, the National Institute for Occupational Safety and Health published a report entitled: *A Proposed National Strategy for the Prevention of Noise-Induced Hearing Loss.* Contributors to this report recommended that national consensus standards for establishing hearing conservation practices should be developed.

In January 1990, the National Institutes of Health and the National Institute on Deafness and Other Communication Disorders held a consensus development conference, "Noise and Hearing Loss." Participants of the conference concluded that hearing loss from non-occupational noise is common, but awareness of the hazards is not. The Report determined that "... inconsistent compliance and spotty enforcement of existing governmental regulations have been the underlying cause of ... relative ineffectiveness in achieving prevention of noise-induced hearing loss." Dr. James B. Snow, Jr., Director of the National Institute on Deafness and Other Communication Disorders, will talk in more detail today about the 1990 Report.

Last year, the Public Health Service of the U.S. Department of Health and Human Services issued a report, *Healthy People 2000: National Health Promotion and Disease Prevention Objectives.* The Report established a set of measurable targets for creating a healthy society by the year 2000. ASHA was one of 300 organizations that provided input into the development of the objectives. ASHA's comments strongly urged inclusion of objectives related to noise. Although the final report does not specifically target environmental noise reduction, the *Research Needs* section of the chapter, entitled *Environmental Health*, does acknowledge the fact that 28 million Americans have impaired hearing, and about 10 million of these cases are associated with loud noise. Contributors to this report advocate "...Additional research on the prevalence and severity of environmental noise pollution ... so that appropriate public health protections can be implemented."

A 1991 report of the Organization for Economic Co-operation and Development contended that, over the past 20 years, the general noise environment and level of noise exposure in the leading industrial democracies has steadily worsened.

Finally, in July 1991, the U.S. House Select Committee on Children, Youth, and Families conducted a hearing to investigate the effects, primarily upon children and young adults, of environmental noise. A prime mover behind this hearing was Representative Richard Durbin (D-IL), who serves on that Committee. ASHA leaders and staff met with Congressman Durbin and members of his staff. Through that initial involvement, the idea for this symposium was born.

Today's symposium brings together professionals from a variety of backgrounds — audiologists, hearing scientists, acoustical engineers, otolaryngologists, community planners, and others. It is this cooperative, collaborative spirit that leads me to be so confident that our meeting will yield constructive results.

I know that the time for planning this event has been exceedingly short. Great demands have been placed on the planning committee, the working group chairs, and the group participants. Even greater demands will fall upon your shoulders today as you are asked to develop and draft consensus documents in each of the nine issue areas.

As you go about your work, you will have as your number one concern the well-being of all Americans who are exposed to dangerous levels of noise.

This is not a conference to re-plow the ground already tilled by the groups and in the Reports that I've just detailed. Rather, it is a meeting to build on the foundation provided by these Reports and develop a realistic approach to reducing the threat of noise-induced hearing loss. We want to look not only at what is desirable, but at what is possible.

Politics has been defined as the art of the possible. Congressman Durbin can help us define just what is and is not possible in the current political climate. I'm sure many of us thought it would be impossible to fly on a commercial airline without exposure to cigarette smoke. After all, the tobacco lobby is very effective. But not always. Congressman Durbin, with the support of millions of Americans, decided it was both desirable and possible to change that situation. Eventually, legislation was enacted that precludes smoking on flights of all duration.

Congressman Durbin has decided that it is not only possible, but desirable, to provide the funds necessary to reactivate the Environmental Protection Agency's Office of Noise Abatement and Control. He and some of his colleagues have introduced legislation to that effect. Until 1981, the Office of Noise Abatement and Control had served as the coordinating mechanism for many of the federal government's noise control activities. State and local government noise control efforts were supported by limited federal financial assistance, but technical support was substantial and effective. The issue of the demise of the Office of Noise Abatement and Control, the possible lapse in state and local activities related to that office's demise, and private efforts at noise control — are subjects for today's meeting.

Whatever course or courses of action this group ultimately recommends, I am convinced that the development of a positive, working relationship with policymakers on Capitol Hill will be important to our goal of reducing environmental noise. Policymakers can benefit from the expertise that you bring to the issue, and we can all benefit from a dose of "political reality" as we design a response to this problem.

Each group will examine the many options available for the reduction, control, and/or elimination of noise in a particular area of deliberation. ASHA has no preconceived notion as to what the final Report of this meeting should or will contain. We know that the problem of noise-induced hearing loss and extra-auditory effects is a serious one. We know that without a concerted effort the problem will only get worse. We know that all segments of American society must be united in efforts to lessen this dangerous threat to our health and productivity. Public education, government measures, private actions, and individual responsibility should unite to produce the appropriate and effective response.

A NATIONAL STRATEGY FOR THE UNITED STATES

Remarks of Representative Richard J. Durbin (D - IL)

Earlier this year, I asked the Select Committee on Children, Youth, and Families to hold a hearing to investigate a few aspects of noise-induced hearing loss. Except for the important research and education activities of the National Institute of Deafness and Other Communication Disorders, I was startled by the lack of clear health policy goals in this area.

Based on what I have read and heard about noise-induced hearing loss and its growing threat to children and adults, I strongly believe that the federal government can no longer ignore this significant public health threat.

One troublesome example cited at the Select Committee's hearing is the lowered military induction standards for potential recruits. Apparently, because so many adolescents show up with high-frequency hearing loss, the military has had to lower its acceptable standards with permissible hearing loss of up to 45 dB at 3000 Hz and 55 dB at 4000 Hz, with no induction standards even specified for 6000 or 8000 Hz. As an expert pointed out, "The communicative performance of individuals with this degree of hearing loss in conditions of background noise, as experienced in military operations, could be seriously degraded."

Disregard for the moment the implications of this statement for the military and those who serve. What impressed me about this example is the fact that obviously something is happening to the hearing of an entire generation of Americans from all socioeconomic and other backgrounds. It seems to me common sense that this should cause alarm.

There are countless other examples of evidence that hearing in young adults is at risk. In this era of budget restraint and deficit concern, what actions can still be taken to deal with this growing problem?

I asked the witnesses at the Select Committee's hearing for their recommendations for federal action. The suggestions ranged from funding the EPA Office of Noise Abatement to providing hearing health education for elementary and secondary school children. All of the recommendations given that day were productive and important. Yet, it was apparent that this important issue, if it is to be successfully addressed, requires more than the suggestions of several witnesses and experts. An effective and workable policy requires a consensus.

In addition, it was apparent to me that members of Congress need to be educated about noise and noise-induced hearing loss — an education not provided by one day of testimony.

So I am here today to ask you — a diverse collection of experts in the area of noise — to discuss strategies for the federal government to combat noise in the 1990s. Your work may not only present a blueprint for federal action, but may also serve to alert members of Congress unaware of the problems with noise.

I realize there are many viewpoints represented here, from people with various backgrounds and not necessarily shared opinions. However, I hope that the diversity of opinion will lead to strategies that can withstand the rigors of the legislative process.

I would also like to say a word about the past. No one would disagree that the federal government fumbled its responsibility once. I cannot predict it will do any better a second time. But I firmly believe that with history as our guide, we can do a far

better job of formulating creative, cost-effective and long-lasting strategies for combating noise.

I would like to mention that Congresswoman Patricia Schroeder, who chairs the Select Committee on Children, Youth, and Families and has worked with me closely on this issue, could not be here today but has left a statement thanking you for your work and encouraging you in these endeavors.

Additionally, I would like to thank Dr. Patrick J. Carney, President of the American Speech-Language-Hearing Association, Dr. Charles Schmid, Executive Director of the Acoustical Society of America, and Dr. Jerome Goldstein, Executive Vice-President of the American Academy of Otolaryngology-Head and Neck Surgery, for their cosponsorship of the conference. As well, I would like to thank Frederick Spahr, Evelyn Cherow, and Sydney Olson of ASHA, for their tremendous work in bringing this conference together.

Again, I want to thank you for taking time out of your busy holiday schedule to help find solutions to the problem of noise. I have been very impressed with those of you whom I have had the pleasure to meet and work with, and I look forward to continuing to work with all of you in the future.

Remarks of Representative Patricia Schroeder (D - CO)

Chairwoman, Select Committee on Children, Youth, and Families

I join my colleague, Representative Durbin, in welcoming experts and advocates to this conference on the development of an effective noise control policy. I wish to thank the participants, including the American Speech-Language-Hearing Association, the American Academy of Otolaryngology-Head and Neck Surgery, and the Acoustical Society of America, for meeting today to seek consensus on this important topic.

In July, the Select Committee on Children, Youth, and Families, which I chair, held a hearing, "Turn It Down: Effects of Noise on Hearing Loss in Children and Youth." Audiologists, otolaryngologists, consumers, educators, and a musician testified that excessive noise presents a serious danger to the hearing of all people. Children today are at particular risk: not only can some of their favorite activities harm their hearing, but increasing noise levels place them in danger of living in the noisiest society in human history.

Yet noise-induced hearing loss *is preventable.* We can protect children and adults from unsafe noise, and educate them to preserve their hearing. Witnesses at the Select Committee hearing recommended re-establishing an office of noise control, putting warning lights or devices on personal stereos, placing labels on tools and appliances, enclosing earplugs with noisy tools, and instituting noise education programs.

Following the hearing, I received calls and letters from people all over the country, expressing concern over noise in their communities, and calling for renewed action by the federal government. Their strong concern indicates that the noise problem is taking a serious toll on people in our cities, suburbs, and rural areas, and that a mandate exists for action.

Last month, Rep. Durbin and I introduced the Office of Noise Abatement and Control Establishment Act of 1991 (H.R. 3710), a bill to restore funding for an office of noise abatement and control within the Environmental Protection Agency. This legislation, which would revive EPA research and enforcement activities, takes a first step in combatting noise.

The recommendations that emerge from this conference will play an important role in defining priorities for legislation and policy implementation. Finding effective approaches that reduce noise and protect hearing will be an increasingly important health strategy in the coming years. I wish you much success in this conference. Together we can take decisive action.

INTRODUCTION

Evelyn Cherow
Alice H. Suter

Noise. Loud, confused, senseless shouting or outcry; a sound that lacks agreeable musical quality or is noticeably unpleasant; any sound that is undesired or interferes with one's hearing of something; an unwanted signal or a disturbance in an electronic communication system. (Webster's Ninth Collegiate Dictionary, 1983)

Noise pollution. Environmental pollution consisting of annoying or harmful noise (as of automobiles or jet airplanes). (Webster's Ninth Collegiate Dictionary, 1983)

In 1972, the 92nd Congress of the United States passed Public Law 92-574, The Noise Control Act of 1972 (NCA), "to control the emission of noise detrimental to the human environment, and for other purposes." In 1978, the Act was amended by the Quiet Communities Act. The rationale for passage summarized in the Findings and Policy section of the law stated:

Sec. 2. (a) The Congress finds-

(1) that inadequately controlled noise presents a growing danger to the health and welfare of the Nation's population, particularly in urban areas;

(2) that the major sources of noise include transportation vehicles and equipment, machinery, appliances, and other products in commerce; and

(3) that, while primary responsibility for control of noise rests with State and local governments, Federal action is essential to deal with major noise sources in commerce, control of which requires national uniformity of treatment.

(b) The Congress declares that it is the policy of the United States to promote an environment for all Americans free from noise that jeopardizes their health and welfare. To that end, it is the purpose of this Act to establish a means for effective coordination of Federal research and activities in noise control, to authorize the establishment of Federal noise emission standards for products distributed in commerce, and to provide information to the public respecting the noise emission and noise reduction characteristics of such products.

To implement this statute, the Administrator of the United States Environmental Protection Agency (EPA) was identified as the individual responsible for coordinating the noise research and noise control programs of all federal agencies. Each federal agency was to consult with the Administrator in prescribing standards or regulations respecting (sic) noise.

In 1981, the United States Office of Management and Budget recommended that no funds be appropriated for the Office of Noise Abatement and Control (ONAC) at the EPA. Since that time, Congress has chosen not to fund ONAC, while leaving the statute which created the office in effect. The result has been to render the EPA impotent to implement its responsibilities in noise control and reduction. As the 1991 report to the Administrative Conference of the United States, "The Dormant Noise Control Act and Options to Abate Noise Pollution," states, "Of the twenty-eight environmental and health and safety statutes passed between 1958 and 1980, the Noise Control

Act of 1972 stands alone in being stripped of budgetary support." (Shapiro & Suter, 1991/ November).

Not surprisingly, the noise pollution problem continues to worsen. In 1991, the Organization for Economic Co-operation and Development (OECD) published a report of a project on noise abatement policies in member countries, *Fighting Noise in the 1990s*. Although the report addressed the status of noise problems and effectiveness of control policies in Australia, France, Germany, Japan, the Netherlands, and Switzerland, it also managed to capture the issues and potential solutions of relevance to the United States. For this reason, the planning committee for this symposium report adopted a similar title to express solidarity with the views of our OECD colleagues.

The OECD (1991) report contends that "analysis of recent trends regarding both exposure to noise and implementation of noise abatement policies gives no ground for optimism as to the future development of the acoustic environment ... Increasing road and air traffic is the main reason for this ... Neighborhood noise is having a considerable impact on populations but measures taken against this form of nuisance seem inadequate in practically all countries ... Changes in noise sources and their continuous rapid growth over recent years constitute a challenge which, on the whole, noise abatement policies pursued in the majority of OECD countries have not succeeded in meeting; nor, have they met the expectations of the public, for which noise is one of its major concerns in regard to the local environment and the quality of life."

The outlook for the United States may be equally dim if the vacuum for coordination of noise control efforts is not filled. Major reports from both public and private agencies over the past several years have urged the restoration of a coordinating federal agency with responsibilities for noise control activities for the United States. (National Institute on Deafness and Other Communication Disorders, 1990; National Institute for Occupational Safety and Health, 1988; Shapiro & Suter, 1991). Until recently, a federal response to these recommendations has not been forthcoming.

A concurrent and relevant trend gaining more attention from policymakers concerns the emphasis on increased health promotion and disease prevention efforts in response to the soaring healthcare costs of the nation. The 1990 U.S. Public Health Service report (1990), *Healthy People 2000: National Health Promotion and Disease Prevention Objectives*, provides measurable targets for creating a healthy society by the year 2000. A section of the report devoted to environmental health includes specific objectives concerning asthma, lead ingestion, waterborne diseases, chemical poisoning, air pollutants, radon, toxic agents, solid waste disposal, and drinking and surface water.

With regard to environmental noise reduction, however, the *Research Needs* section of the chapter, *Environmental Health*, states:

> Over 21 million Americans suffer hearing impairment. In 1988, 90.8 per 1000 people had hearing impairments and 7.5 per 1000 were deaf in both ears. There are approximately 28 million people in the United States with impaired hearing. Approximately 10 million of these cases are associated with loud noise. For many of these individuals, exposure to occupational and recreational noise has caused irreversible damage to the inner ear. However, it is unclear whether the incidence of hearing impairment has risen in recent years, because few studies of noise-induced hearing loss have been conducted. Additional research on the prevalence and severity of environmental noise pollution is needed so that appropriate public health protections can be implemented. (p.335)

The report charges EPA with the responsibility for regulating environmental hazards but neglects to identify noise as one of the pollutants for which EPA has legal jurisdiction. In addition, the report, *Healthy People 2000*, overlooks current research findings found in critical reports from other federal agencies. One can only assume that the lack of a federal coordinating agency serving as a resource on noise effects and policies led to this omission.

With this knowledge, Rep. Richard Durbin (D-IL) initiated congressional hearings and this symposium to hear from the professional community of national experts on noise about the current status of noise problems in this country and the appropriate federal action needed to address these concerns. Over 120 professional experts convened at the American Speech-Language-Hearing Association (ASHA) headquarters in Rockville, Maryland to synthesize the findings that have preceded this meeting and offer concrete solutions to the current noise policy dilemma facing our legislators. A unique coalition of organizations consisting of ASHA, the sponsoring organization, and co-

sponsors, the Acoustical Society of America, and the American Academy of Otolaryngology - Head and Neck Surgery, merged resources to support symposium activities.

Nine working groups were identified: Hearing Loss: Occupational and Non-occupational (I); Physiological and Psychological Effects (II); Speech, Sleep, and Community Annoyance (III); Stationary Noise Sources (IV); Mobile Noise Sources (V); Consumer Noise Sources and Hearing Protection (VI); Public Information and Education (VII); State and Local Strategies (VIII); and Regulatory Alternatives (IX). Each group deliberated and came to consensus on recommendations specific to their topic area. Those detailed recommendations are listed within the chapters that follow. A brief summary of key symposium recommendations is found here.

Conference Summary

There was general agreement among conference participants that excessive noise represents a threat to the public health and welfare, and that a strong federal program should be re-established to serve the public's needs. Most agreed that the logical home of this program is the United States Environmental Protection Agency (EPA). This noise program should play a coordinating role among federal, state, local, and private organizations, and it should encourage all federal agencies to enforce their existing noise regulations. Approaches to noise abatement, such as product labeling, national and international consensus standards, and various types of incentives should be given the most serious consideration. Certain research programs need to be undertaken and criteria need to be revised. National trends in noise exposure need to be updated, and the physiological and psychological effects of noise need to be further explored, as do the effects of noise on sleep, speech, and annoyance. Financial and technical assistance to state and local noise programs should be resumed. A serious need exists for public information and education so that informed individuals may choose quieter products and environments.

Individual Group Summaries

I. ***Hearing Loss: Occupational and Non-occupational.*** Working Group I relied upon two source documents: (a) The *NIH Consensus Statement on Noise and Hearing Loss* (see Appendix I) and (b) the *NIOSH Proposed National Strategy for the Prevention of Noise-Induced Hearing Loss.* Many of the working group's members had participated in the development of both documents, and the group endorsed the findings and recommendations of these reports. Specifically, the working group's recommendations are:

- The federal government should enforce existing noise regulations and apply them uniformly across the industrial work force.
- A program should be established to coordinate the federal effort to limit noise exposure and protect hearing.
- A national educational program in the prevention of noise-induced hearing loss is needed for professionals and for the general public.

II. ***Physiological and Psychological Effects.*** Working Group II agreed that while not unequivocal, research evidence suggests that prolonged exposure to noise levels found in many factories and extreme community environments can cause adverse physiological effects, most notably increases in blood pressure. Despite the associative evidence, however, consensus is still lacking as to whether or not noise directly *causes* these effects. Therefore, the group offered the following recommendations:

- Epidemiological, human laboratory, and animal-model research should be supported using a coordinated, integrated strategy.
- Certain psychological effects need to be explored further with prospective studies. The complex relationships between psychological and physiological variables need to be examined more closely to provide crucial information about the mechanisms underlying physiological outcomes.
- EPA should provide the funding, with the possible involvement of other agencies, and agencies and national centers of excellence should be established to undertake such interdisciplinary research.

III. ***Speech, Sleep, and Community Annoyance.*** Working Group III's recommendations are:

- A central agency should be established to represent the broad public interest in environmental noise impacts. This agency should have primary responsibility for

collecting, interpreting, and disseminating noise-related information and research findings.

- Major research needs concern the impact of noise in remote, rural environments, the impact of infrequent and low-level noises, and the effects of impulsive sounds.
- The Day-Night Average Sound Level (DNL) is a widely useful descriptor of environmental noise exposure and a predictor of the prevalence of annoyance in residential communities. However, additional specialized metrics may be useful in environments such as schools, lecture halls, hospitals, outdoor recreation, and low population density areas, and for unusual circumstances of noise exposure.

*IV. **Stationary Noise Sources.*** Working Group IV concentrated on stationary noise sources, including industrial machinery and its components and complete industrial facilities and recommended:

- Because noise-induced hearing loss is a major concern, equal protection, including hearing conservation requirements, should be extended to all employees in all industries.
- A federal entity should oversee such noise activities as labeling the acoustic power of industrial machinery, assisting state and local governments, coordinating all noise activities in the United States, sponsoring research into noise control techniques, and educating the public.
- There is a need for incentives, in the form of economic benefits and public recognition, to encourage industry to control noise.

*V. **Mobile Noise Sources.*** Working Group V recommended the noise office in the EPA should be established. This office should be staffed by highly qualified individuals and it should provide leadership and coordination, foster international trade by reducing noise-related trade barriers, and engage in product noise labeling.

- The Noise Office should address the growing public concern about noise by helping to define noise impacts, guiding criteria development, and functioning as a citizens' advocate, particularly in the area of aircraft noise.
- The Noise Office should have limited regulatory powers, but should work cooperatively with other agencies, help re-establish state and local noise programs and disseminate information, and by doing so, assist in the maintenance and improvement of the quality of life.
- Source noise control for railroads and aircraft should reside in the Department of Transportation, and local governments should be permitted to control noise from rail yards.

*VI. **Consumer Noise Sources and Hearing Protection.*** Working Group VI's recommendations are:

- The most efficient and effective means to respond to the problems created by noisy consumer products is to charge a federal agency with noise abatement, such as EPA's Office of Noise Abatement.
- One of the noise agency's principal tasks should be the development of regulations for the labeling of noisy consumer products with both noise hazard and sound level ratings, and revision of the existing hearing protector Noise Reduction Ratings (NRRs) to provide truly useful data. The labels would warn consumers about actions they should take to protect themselves, and provide information to assist them in making informed purchasing decisions, thus creating an incentive for the development of quieter products.
- The federal noise program should support research to obtain data characterizing the typical noise doses of non-occupationally noise-exposed adults and children.

*VII. **Public Information and Education.*** Working Group VII identified a great need to provide meaningful education to the public about how to prevent the harmful and annoying effects of noise. An educated public that knows more about product selection and noise abatement could take a more active role in achieving a quieter environment.

- Target groups for public information and education must include children and youth, adult citizens and consumers, training programs, practitioners in influential professions, and specific groups at higher risk.

- To achieve the maximum impact, educational efforts should follow current health promotion techniques for establishing and maintaining behavior change.

VIII. State and Local Strategies. Working Group VIII's recommendations are:

- Re-establish an entity (e.g., the Office of Noise Abatement and Control) within EPA that would be an advocate for regulatory and non-regulatory community noise management.
- Funding for this noise office should be appropriated, including support for state and local grants, for which criteria and mechanisms should be developed.
- To encourage a process of innovation and information feedback, earlier initiatives similar to the "Each Community Helps Others" (ECHO) program and the Technical Assistance centers should be re-established, along with developing an electronic interactive communication system for information exchanges.
- State and local noise strategies involving both public and private sector approaches should be initiated.
- Model community noise ordinances and basic education and training should be provided to private sector individuals as well as to state and local noise officials.

IX. Regulatory Alternatives. The main recommendations of Working Group IX are:

- The funding of EPA's Office of Noise Abatement and Control.
- Establishment of a national noise control action plan.
- Distribution of responsibilities among federal agencies and among federal, state, and local governments.
- Requirements for noise source testing by accredited laboratories.
- The crucial baseline documents, such as the *Levels Document* and the *Guidelines for Preparing Environmental Impact Statements on Noise*, should be updated, and trends in national noise exposure and abatement in compliance with the Noise Control Act of 1972 should be documented.
- Federal support and participation in national and international noise standards efforts should be implemented. These standards activities would be cost-effective and in the national interest, with respect to foreign trade and competitiveness.
- The EPA's noise office would benefit from the use of technical advisory committees through the National Research Council.

The work of this conference was accomplished through the collaborative efforts of audiologists, hearing scientists, acoustical engineers, land-use planners, and otolaryngologists who believe that noise has deleterious effects on the health and welfare of children and adults—our families, friends, colleagues, and clients. The symposium report offers strategies for affecting change in the noise control policy of our nation and for ensuring international cooperation in the noise abatement arena.

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NOISE IN THE UNITED STATES

Alice H. Suter

It has been nearly 10 years since the Environmental Protection Agency's (EPA) Office of Noise Abatement was closed. The stated reason for cutting off its funding was that most noise problems are highly localized, and states and localities should have the opportunity and the responsibility to direct their own noise programs.

But the de-emphasis on regulation and on a strong federal program produced a very different effect. States and localities suffered from the loss of federal leadership and technical support, as well as reduced budgets, and their noise programs have all but disappeared. Moreover, the loss of federal leadership from EPA has prompted other federal agencies to cut their noise programs. In addition, several of EPA's noise regulations have remained on the books to pre-empt efforts by states or localities to tighten or modernize them. And yet, virtually all of these regulations are unenforced.

Not all noise activities have been in hibernation since 1982. Some noise sources continue to be researched and controlled. Noise measurement instrumentation has been considerably improved, and there has been a fair amount of research on noise effects, much of it by our European colleagues. In general, however, there has been a decline in the prevention, research, and control of noise in the United States.

Perhaps those who closed the EPA's Noise Office thought that the problem would go away. It hasn't.

The population of the United States has increased about 11% over the past decade, and the rate of growth in urban areas is twice that of non-metropolitan areas. Because noise levels in communities are directly related to population density, it is safe to assume that the noise problem is increasing at least as rapidly as the population. Noise from certain sources appears to be increasing at a faster pace than the population. A brief summary of the various noise sources would be helpful here:

Road traffic noise was the leading source of community noise a decade ago, and probably remains so today. The number of trucks registered in the United States increased about 35% between 1980 and 1989. Noise from buses, automobiles, and motorcycles contributes to the traffic noise problem as well.

Air traffic also appears to be increasing more rapidly than the U.S. population. Between 1980 and 1990 there was a 79% increase in passenger mileage and an 86% increase in air freight mileage. The introduction of Stage III aircraft should promote a quieter environment, but the phase-out will occur gradually over the next 12 years. The growth of air transportation and the pressing need for airport expansion threatens to offset these benefits.

The impact of noise from ***railroads*** may actually have decreased because rail traffic seems to have decreased during the last decade. However, noise from engines, horns, and whistles, as well as from switching and shunting operations, can and does still impact neighboring communities and railroad workers.

The ***construction industry*** has done well over the past decade, although activity has slowed recently. The construction gross national product (GNP) has increased by 153% since 1977, and the

number of construction workers has increased about 21% since 1980. This increased activity was most likely accompanied by increased noise.

The extent of the noise emission problem in the manufacturing industries has probably not increased significantly in recent years. Although the industrial GNP has grown, the work force has declined. From the worker's perspective, occupational hearing loss is still a very serious problem, and the Occupational Safety and Health Administration's reluctance to enforce the requirements for engineering controls certainly has not helped.

Noise within buildings, such as amplified music, voices, and footfalls continues to be the most frequent environmental complaint of apartment dwellers. It appears that the knowledge to solve these problems is not being applied, and, in fact, the quality of construction is declining.

Noise from consumer products is no less than it was 10 years ago, and probably greater because of the introduction of numerous new products, such as gasoline-powered leaf blowers and noisy toys. Noise from certain recreational activities, like sporting events and "boom cars," appears to be on the rise, increasing the likelihood of non-occupational hearing loss.

In 1974, EPA estimated that nearly 100 million Americans lived in areas where daily average noise levels exceeded its identified safe level of 55 dB. This number is likely to be somewhat higher today, but current estimates are not available for the United States.

During this meeting we will attempt to sort through the many noise issues, decide what needs to be done, in what order and how, and basically plan a strategy for the nation. It is an awesome task.

While we do our work we need to remember that noise is a quality-of-life issue. It doesn't kill people or make them visibly sick. Some, therefore, would give it a relatively low priority. But the quality of life is very important to someone whose solitude is shattered by a low-flying military aircraft while hiking in the mountains. It is also important to the light sleeper who is awakened habitually by early-morning refuse collection, and to the apartment dweller who is chronically subjected to the pounding of a neighbor's stereo. The worker whose hearing has been impaired by long-term exposure to noise has lost a portion of life's quality forever.

The quality of life also has a bearing on stress, and, as we all know, stress can be caused or exacerbated by noise. Nowadays, the relationship between stress and health is becoming increasingly clear.

The purpose of the Noise Control Act of 1972 was to protect the public health and welfare, and it is important to note that the statute never separates the terms *health* and *welfare*. This is in the tradition of the World Health Organization, and EPA followed this policy throughout its "Criteria" and "Levels" documents, and its regulatory activities. Health and welfare are never separated. To separate health and welfare would tend to trivialize the annoyance effects and to draw an artificial distinction, although this is exactly what some are trying to do.

Most reasonable people would agree that we need a strong national noise program, and the logical place to begin would be to initiate the reopening of EPA's noise office. Congressman Durbin has done just that by introducing legislation to fund the Office of Noise Abatement and Control at EPA.

Unfortunately, there are some whose memories of EPA's Office of Noise Abatement are not pleasant, and who would be inclined either to oppose any federal noise program or to fragment it by dividing the responsibilities among several agencies. To do this, however, would be to throw the proverbial baby out with its bath water. Just as we didn't terminate the space program when the Challenger blew up, we shouldn't oppose the resuscitation of EPA's noise program.

There is no doubt that EPA's Noise Office was unpopular at times, especially among those whose activities or products were regulated. But a new Noise Office would have a new staff, new ways of approaching problems, and a new personality. There is a lot of work for such a program, and the nation needs it.

ENVIRONMENTAL NOISE: AN INTERNATIONAL PERSPECTIVE

Clifford R. Bragdon

Introduction

The issue of environmental noise is not limited by any geographical or political boundaries. This is particularly apparent as we transport people, goods, and natural resources in the global economy. Noise is being experienced on a world-wide international basis.

All of this activity occurs within the earth's biosphere, which is the life support system for the world's population. The strategic planning of this three-dimensional space is critical for human survival, and noise is one of the environmental attributes that can diminish human comfort and enjoyment (Figure 1).

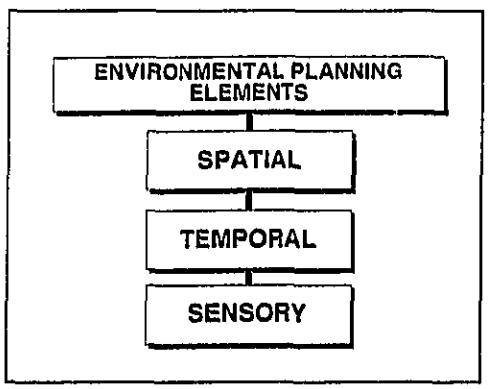

Figure 1
Three strategic elements for environmental planning.

There are at least seven factors that are contributing to the issue of noise and strategies for this control from an international perspective.

Source Growth

The sources of noise that contribute to an increasing ambient condition are growing in absolute terms. In western Europe, for example, commercial air transportation traffic is growing at a rate of 10% per year, as reported by the Organization for Economic Co-operation and Development (OECD). Surface transportation, particularly automobiles and trucks are increasing in substantial numbers as well, which is having an impact upon community response to noise. Disturbance associated with vehicle noise is up 70% over the past 25 years in The Netherlands.

Source Power

The source of power (e.g., engine output) appears to be increasing along with the number of sources. Greater pay loads are necessary to maximize profits, which require more engine displacement. Oftentimes these larger power plants, whether they be stationary or mobile, generate higher levels of noise. To some extent this can be offset by improved design and noise performance standards. High-speed rail using larger propulsion systems appears to be the most significant transit-based noise problem.

Source Mobility

Mobility appears to be the backbone to our transportation-based economic system. Transportation corridors are growing on a three-dimensional basis: aerial, surface, and subsurface (Figure 2).

Airspace allocated for air-traffic control for both military and civilian activity continues to grow. At the surface level, the roadways, railroad, and waterways combined with air constitute over 4.5 million miles in the United States. This contributes to more travel and associated noise. In the past 15 years, vehicles miles have nearly doubled.

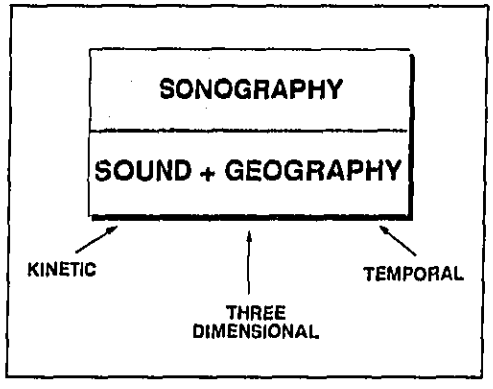

Figure 2
Sonography: A three-dimensional perspective of sound – both static and kinetic.

Source of Replacement

Certain sources are being replaced or recycled. Frequently, they are removed from the circulation and quieter more energy-efficient products are introduced. This is now occurring with the introduction of Stage 3 aircraft by both the Federal Aviation Administration (FAA), and the International Civil Aviation Organization (ICAO) member countries. In some instances, these earlier generation aircraft (i.e., Stage 1 and 2), remain in circulation and are being found in many third-world countries, thereby exporting the noise problem to new locations as those countries try to improve their economic condition.

Population Growth

There is a direct relationship between population size and noise generation, as reported by the United States Environmental Protection Agency. The world's population continues to grow in absolute terms, with countries experiencing varying growth rates which in turn produces greater levels of noise. In certain more industrialized countries having relatively stable populations, noise control regulations are very comprehensive and stringent.

Population Distribution

The settlement patterns of the population and their geographical distribution in relationship to noise-related sources (i.e., roadways, airports, power stations, heavy manufacturing) can be of strategic importance. Population densities continue to rise, placing increasing pressures on human settlement patterns being exposed to noise-related sources. There are 20 urban areas worldwide that have populations per square mile from 55,000 (Caracas, Venezuela) up to 270,000 (Hong Kong). At least 17 countries have installed permanent airport noise monitoring systems in the vicinity of selected airports for evaluating this noise source and its impact on the population (Figure 3). Noise surveillance systems along with other environmental sensors will be more commonplace in the future.

Country	Number	County	Number
United States	23	Denmark	1
West Germany	8	Greece	1
England	3	Hungary	1
Canada	3	Indonesia	1
France	3	Israel	1
Spain	3	Italy	1
Austria	2	Netherlands	1
Japan	2		
Switzerland	2	TOTAL	56

Figure 3
Permanent civil airport noise monitoring systems international.

Space Use Planning and Management

Because space and time are finite resources, it is critical that they be managed in a very effective manner. The word "space" must be substituted for "land-use" in planning because we are dealing with three planes that are composed of varying elements (i.e., air, earth, water) (Figure 4). Stringent space use controls are in place for planning new settlements with specific noise protection areas, such as those established in Germany. The largest civil airport sound insulation program resides in England where over 50,000 dwellings have been treated at a cost of over 34 million pounds. Depending upon the country, there are both proactive and reactive noise complaints. In certain countries

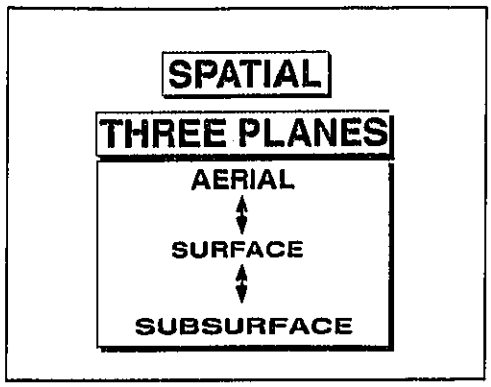

Figure 4
The three-dimensional planes associated with a spatial environment.

such as France, they are more proactive where pilot towns are given a 50% subsidiary for 3 years to reduce noise by traffic management, noise mapping, and related town planning techniques.

A variety of strategies for controlling noise can be found throughout the world. These techniques can exist in many countries of the world. Noise control strategies are extremely important as the world's population continues to grow and population densities increase, all of which challenge our three-dimensional vision for protecting man's biosphere. The European Community is moving further to lower noise limits along with ICAO. The North Atlantic Treaty Organization (NATO) and the Committee on the Challenges of Modern Society have given focus to the issue of aircraft noise and control among the member counties. The most effective solutions to minimize noise must be done on an international playing field.

SUMMARY OF THE NIDCD NOISE AND HEARING LOSS CONSENSUS CONFERENCE

James B. Snow, Jr.

I want to thank the organizers of this symposium for inviting me to present a summary of the Noise and Hearing Loss Consensus Conference, held at the National Institutes of Health on January 22-24, 1990, and sponsored by the National Institute on Deafness and Other Communication Disorders (NIDCD) and the Office of Medical Applications of Research.

As you may know, the NIDCD has as its mission the support of research and research training in the normal and disordered processes of hearing, balance, smell, taste, voice, speech, and language. As the Institute responsible for research in human communication, NIDCD is extremely interested in the effect of noise on human hearing. Research projects in the hearing area receive 59% of the NIDCD's current grant support. We know that of the 28 million Americans who suffer from hearing loss, 10 million have noise-induced hearing loss. We also know that 20 million people in the United States are exposed, on a regular basis, to dangerous levels of noise in their occupations. Noise-induced hearing loss (NIHL) also occurs in non-occupational settings, principally in small arms fire as in target practice and hunting and in the use of power tools. It is now recognized that noise-induced hearing loss begins in late childhood and the teenage years, particularly in boys.

Conclusions and Recommendations

Several of the conclusions and recommendations from the *Noise and Hearing Loss Consensus Statement* (see Appendix I) should be helpful as background information for your work today.

The conferees concluded that:

- Sounds of sufficient intensity and duration will damage the ear and result in temporary or permanent hearing loss at any age.
- NIHL is characterized by specific anatomic and physiologic changes in the inner ear.
- Sounds with levels less than 75 dB(A), even after long exposures, are unlikely to cause permanent hearing loss. However, sounds with levels above 85 dB(A) with exposures of 8 hours per day will produce permanent hearing loss after many years.
- There is a broad range of individual differences among people in the amount of hearing loss each suffers as a result of identical exposures. This fact is especially important when combined with the concept that current scientific knowledge is inadequate to predict that any particular individual will be safe when exposed to a hazardous noise.

Participants recommended that:

- Because sources of potentially hazardous sound are present in both occupational and non-occupational settings, personal hearing protection should be used when hazardous exposures are unavoidable.
- Vigorous enforcement of existing regulations, particularly for the workplace, and consumer product labeling would significantly reduce the risk of workplace NIHL. Regulations should be broadened to encompass all employees with hazardous noise exposures.

- Application of existing technologies for source noise control, especially in the manufacture of new equipment and construction of new facilities, would significantly reduce sound levels at the ear.
- In addition to existing hearing conservation programs, a comprehensive program of education regarding the causes and prevention of noise-induced hearing loss should be developed and disseminated with specific attention directed toward educating school-age children.

Hearing loss from non-occupational noise is common, but public awareness of the hazard is low. Educational programs should be targeted toward children, parents, hobby groups, public role models, and professionals in influential positions such as teachers, physicians, audiologists, and other healthcare professionals, engineers, architects, and legislators. In particular, primary healthcare physicians and educators who deal with young people should be targeted through their professional organizations. Consumers need guidance and product noise labeling to assist them in purchasing quieter devices and in implementing exposure reduction strategies. The public should be made aware of the availability of affordable, effective hearing protectors (e.g., ear plugs, ear muffs, and canal caps). Hearing protection manufacturers should supply comprehensive instructions concerning proper protector use and also be encouraged to increase device availability to the public sector.

The NIDCD has already begun a project to reach children. We have developed a videotape and teacher guide for children in grades 3 through 6. These children are at a point in their development where they are known to feel some responsibility for their own welfare. We want elementary school students to become interested in protecting their own hearing and to become interested in the biology of hearing at the same time. Children in this age group have been important in various environmental efforts including recycling. The NIDCD wants them to become involved in protecting themselves against the most preventable form of hearing loss, noise-induced hearing loss, before they are in junior high-school with its increased unsupervised use of equipment, amplified sound, and other sources of dangerous noise levels.

Hearing conservation must begin by providing each individual with basic information. NIHL is insidious, permanent, and irreparable, causing communication interference that can substantially affect the quality of life. Ringing in the ears and muffling of sounds after sound exposure are indicators of potential hazard. Dangerous sound exposures can cause significant damage without pain, and hearing aids do not restore normal hearing. Individuals should become aware of loud noise situations and avoid them if possible or properly use hearing protection. It is important to recognize that both the level of the noise and its duration (i.e., exposure) contribute to the overall risk. Certain noises, such as explosions, may cause immediate, permanent damage.

Many sources, such as guns, power tools, chain saws, outboard motors, small airplanes, farm vehicles, firecrackers, some types of toys, and some medical and dental instruments may produce dangerous exposures. Music concerts, car and motorcycle races, and other spectator events often produce sound levels that warrant hearing protection. Similarly some stereo headphones and loudspeakers are capable of producing hazardous exposures. Parents should exercise special care in supervising the use of personal headset listening devices, and adults and children alike should learn to operate them at safe volume settings.

The central message of the Consensus Conference is that noise-induced hearing loss is entirely preventable through personal hearing protection. Public health education regarding noise exposure should begin early in life and emphasize avoidance of high-risk activity such as small arms fire and use of power tools without ear plugs or ear muffs.

WORKING GROUP I
HEARING LOSS: OCCUPATIONAL AND NON-OCCUPATIONAL

William W. Clark and Paul R. Lambert - Co-chairs

Introduction

The association between noise exposure and hearing loss has been observed for centuries and, since the 1800s, has been documented in a number of epidemiologic studies of workers exposed to various occupational noises.

Approximately 25% of this nation's industrial work force that is, over 6 million men and women continue to be exposed to hazardous noise. The number of individuals exposed to annoying environmental sound, unrelated to occupation, far exceeds these figures, and in fact, affects each of us.

Noise damage to the ear may be instantaneous or insidious. Various parameters of the noise determine the onset and extent of injury. These parameters include intensity, duration, frequency content, and scheduling of exposure - that is, whether the noise is continuous or intermittent.

With exposure to continuous sound pressure levels between 80 and 130 dBA, permanent injury to the cochlea results from metabolic changes within the sensory receptors or hair cells, and/or damage to their stereocilia. Complete degeneration of hair cells with scar formation can occur. These pathologic processes, although not completely understood, have been extensively studied in animal models. The term *noise-induced hearing loss* (NIHL) is used to describe these processes, and they represent the most common mechanism of inner ear damage from noise in the workplace. This hearing loss usually develops over months and years, and too often it is first detected only when speech understanding deteriorates - a time when extensive injury to the cochlea has already occurred.

If peak sound pressure levels exceed approximately 140 dBA, which can be caused by explosions such as those produced by a firecracker, toy cap pistol, hunting rifle or shotgun, an instantaneous loss of hearing due to mechanical disruption or tearing of inner ear tissues may result; this is termed *acoustic trauma*. The fact that such hearing loss is usually secondary to non-occupational noise sources, and occurs in a society that should know better, is distressing to all of us interested in hearing conservation.

The first regulatory action by the United States government with respect to occupational noise was the Walsh-Healy Public Contracts Act in 1969. In 1971, the Occupational Safety and Health Administration (OSHA) promulgated an occupational noise standard (CFR 29, 1910.95) for manufacturers involved in interstate commerce. This 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 dB increase or decrease in level, the permissible exposure time is halved or doubled, respectively). In 1983, OSHA issued an amendment to this standard requiring that a hearing conservation program be instituted if workers were exposed to TWA noise levels of 85 dBA.

The recently adopted international standard, ISO: 1999, provides information on the efficacy of this occupational noise regulation. Evaluation of the risk of sustaining a hearing handicap for individuals exposed chronically below 90 dBA suggests that

the occupational noise standard, as it presently exists, does provide reasonable protection against NIHL.

Quite simply, the problem has been the failure to fully implement and enforce these regulations. The Occupational Safety and Health Administration has been criticized for not fully enforcing these regulations in workplaces covered by the OSHA hearing conservation amendment. Furthermore, workers in agriculture, construction, oil and gas refining, and mining are either not covered by the occupational noise standard, or operate under less rigorous standards. There is no reason for individuals in different occupations to have different noise standards.

All government regulations to date pertain to occupational noise exposure. Of equal concern, however, is the pervasive noise in our home and recreational environments. It has been suggested that impulse noise, especially from guns, may well be the most important cause of NIHL in the general population, not by the gradual destruction of hair cells through repeated daily exposure, but rather by the sudden severe trauma to the inner ear after a single event. Unfortunately, public awareness of the hazards of noise is low, and the prevalence of hunting and target practicing high, approaching 50% of industrial workers. Intervention to include at least consumer product labelling and public education are clearly needed, and should have equal emphasis with strategies to combat occupational noise.

In summary, the problem of occupational and non-occupational hearing loss is easily conceptualized. The agent and the effect are identifiable and measurable. Effective means to limit the deleterious consequences of excessive noise exist. It is the purpose of this working group to consider several recommendations directed at the problem of NIHL.

Summary of Working Group Discussion

The discussion of the working group centered around the nature of the recommendations that were to be made. It was decided to make all recommendations clear, succinct, and general rather than specific in nature. The members of the working group discussed and approved all the recommendations contained in this report.

It should be noted that two source documents were provided to and utilized by the working group: the *NIH Consensus Statement on Noise and Hearing Loss* and the *Proposed National Strategy for the Prevention of Noise-Induced Hearing Loss*, developed by the National Institute for Occupational Safety and Health. Many of the working group members participated in the development of both documents, and the information in these reports provided a foundation for the discussion and recommendations of this working group.

The following recommendations are provided to address the prevention of noise-induced hearing loss. The recommendations contained herein should be applicable to occupational and non-occupational losses. However, it should be maintained that occupationally related hearing loss is currently addressed by OSHA in 29 CFR 1910.95 and this standard has proved to be successful in preventing occupational noise induced hearing loss *if* implemented and managed properly.

Recommendations

1. Enforce existing federal regulations across all government agencies and/or noise exposed populations with time-weighted average exposures that equal or exceed 85 dBA (e.g., OSHA Occupational Noise Standard of 1972 and Hearing Conservation Amendment of 1983).
2. Develop noise exposure and enforcement criteria that are uniformly applied across all industrial, government, and military populations.
3. Identify a federal entity that coordinates the federal effort to limit noise exposure and promote hearing conservation. This entity would also be responsible for evaluation and oversight of federal programs. A second, independent entity, such as the Committee on Hearing, Acoustics, and Bioacoustics (CHABA) should be assigned to evaluate the success of the program.
4. Emphasize noise control at the source as a mechanism for reducing hazardous noise exposures. The federal government should provide incentives to accomplish this objective.
5. Develop educational programs (including product labeling) regarding noise-induced hearing loss for the public and for professionals.
6. Continue to support research on the effects of noise on hearing.

WORKING GROUP I MEMBERS

William W. Clark, PhD - Co-chair
Senior Research Scientist
Central Institute for the Deaf
Chair, Graduate Program in Communication Sciences
Washington University
St. Louis, MO 63110

Paul R. Lambert, MD - Co-chair
Professor of Otolaryngology-Head and Neck Surgery
Director of Otology-Neurotology
Department of Otolaryngology-Head and Neck Surgery
University of Virginia
Health Sciences Center, Box 430
Charlottesville, VA 22908

Rona Glaser, MA
Manager, Hearing Conservation Program
3M Medical Department
3M Center, Building 220-2E-02
St. Paul, MN 55144-1000

Charles E. Jackson, CIH
Chairman, Noise Committee
American Industrial Hygiene Association
Westvaco
5600 Virginia Avenue
North Charleston, SC 29411

David M. Lipscomb, PhD
President, Correct Services, Inc.
P.O. Box 1680
Stanwood, WA 98292

William Melnick, PhD
Professor, Department of Otolaryngology
University Hospital Clinic
456 W. 10th Avenue, Room 4024
Columbus, OH 43210

John H. Mills, PhD
Professor and Vice Chairman
Department of Otolaryngology and Communication Sciences
Medical University of South Carolina
Charleston, SC 29425

Larry H. Royster, PhD
Professor, Department of Mechanical and Aerospace Engineering
North Carolina State University
Raleigh, NC 27695-7910

Andrew P. Stewart, MA
Director, Audiological Services
Ennis, Lumsden, Boylston and Associates, Inc.
605 Eastowne Drive
Chapel Hill, NC 27514

WORKING GROUP II
PHYSIOLOGICAL AND PSYCHOLOGICAL EFFECTS

Ernest A. Peterson, Jerome E. Singer, Shirley J. Thompson - Co-chairs

Introduction[1]

Historical Perspective

Laboratory investigations of the behavioral, psychological, and physiological effects of noise began in the third quarter of the 19th century. Because the experiments were acute and because stimuli could not be described in quantitative terms, these studies are only of historical interest. They offer little insight into the relation between protracted exposure to high levels of noise and health.

During the first several decades of this century, considerable information was gathered about the effects of noise on performance, particularly in the work setting, as well as about acute physiological and psychological reactions. Regrettably, contemporary science popularizers in this country have exaggerated the meager evidence regarding potential health effects of noise in such lurid and moralistic terms that the scientific community eventually adopted an attitude of vigorous skepticism which has persisted to this day. It is perhaps no accident that under 10% of all epidemiological research in this field has been undertaken in North America.

A significant increase in physiological effects research occurred during the two decades between 1960 and 1980. A large and diverse literature was contributed to principally by workers from eastern and western Europe and the Soviet Union. These studies reflected animal-model, human-laboratory, and epidemiological approaches to the problem of noise and health. Some good, but mostly bad, examples of science accumulated during this era. A profusion of acute and long-term harmful effects were reported.

The largest and most coherent portion of the literature focused on various cardiovascular effects. It is not surprising, in view of the long-recognized role that hypertension plays as a major risk factor for heart and circulatory disease, that two-thirds of the epidemiological work investigated blood pressure regulation. Eighty percent of these reported positive findings. Prevalence ratios between high- and low-noise groups averaged roughly 2.5 and data from at least one group described a dose-response relationship. The preponderance of animal-model research substantiated such results, but observations from short-term laboratory experiments using human subjects were contradictory.

Despite this apparently substantial body of epidemiological and animal-model evidence favoring the position that exposure to high levels of noise can raise blood pressure, a number of contemporary reviewers concluded that the evidence gathering techniques were insufficient to prove or disprove a causal relationship.

In many cases, animal and human studies were flawed as well. With regard to the former, experiments were short-lived, stimulus levels were unrealistic and inappropriate to the curve of audibility for the particular species under study, few confounders were accounted for, and the most common animal models chosen, rodents and lagomorphs, are phyletically removed from humans. With one exception, human laboratory studies also were

[1] An annotated and more detailed version of this chapter may be obtained from Ernest A. Peterson, University of Miami School of Medicine, Division of Auditory Research, D7-1, P.O. Box 016960, Miami, FL 33101.

short-lived, their results were conflicting, and the relation of acute to chronic responses remains obscure.

As in the previous 20 years, studies carried out over the past decade have been predominantly concerned with cardiovascular outcomes, especially elevated blood pressure. Hypertension is a major risk factor for coronary heart disease and stroke that continues to be the first and third causes of death in the United States. It is estimated that approximately 60 million Americans have elevated blood pressure. For a very large proportion of these cases, causes are not known. Thus, the health implications of a cause-effect relationship between noise and hypertension would be considerable.

Work can be grouped with regard to the independent variable. Interest has been on the effects of four kinds of noise patterns: (a) community noise, generally involving dwelling intrusions from ground and air transportation, including sonic booms; (b) industrial noise; (c) military low-altitude flyover (MLAF) noise; and (d) laboratory-generated noise or miscellaneous combinations of these patterns. Most of the 31 epidemiological investigations published in the English language, have studied the effects of traffic and industrial noise. Results, especially with regard to traffic noise, have been mixed with slightly more positive than negative findings.

It is clear that the current state of technical knowledge does not support a consistent, nor a quantitative dose-response relationship between noise exposure and cardiovascular disorders. However, this cannot be construed as evidence of no effect of noise exposure on non-auditory health because of the poor quality of the studies. Noise levels and noise control measures have changed. No population-based studies have specifically examined the long-term effects of noise on blood pressure with and without the use of hearing protectors. Studies show that there is a broad range of individual differences in sensitivity to any given noise exposure. There may be many intermediate variables (effect modifiers) along a causal pathway for which noise exposure has an effect within some but not all categories. Furthermore these variables may interact in complex ways. Potential effect modifiers which have been identified include appraisal of noise as a stressor, degree of hearing impairment, noise annoyance, perception of control of noise, noise coping strategies, working conditions, and genetic factors such as family history. Thus it is difficult to define non-auditory risk due to noise since there does not appear to be a purely energy-related dose-response relationship with noise exposure as has been demonstrated with hearing loss.

Although the observed risk from environmental noise on cardiovascular events, especially blood pressure changes, is likely to be small, (maybe too small to be demonstrated with statistical significance in epidemiologic studies), an increase in risk of only 10% can be important in terms of health policy due to the high percentage of exposed population. A 10% increase in risk of cardiovascular disease has been estimated to represent an absolute increase of about 200 cases per 100,000 at risk per year.

Perhaps the most prudent conclusion to be drawn from a review of work in this area is that current findings indicate only that further rigorous studies of non-auditory noise effects are greatly needed.

Psychological Effects Of Noise

The psychological effects of noise can be grouped into three broad categories:

1. the cognitive,
2. the behavioral, and
3. the physiological.

Cognitive effects of noise are composed of annoyance, disturbance, attitudinal, and, perhaps, such other variables as self reports of sleep disturbance. The most common studies of noise's cognitive effects have been of annoyance—studies that are usually conducted in conjunction with noise surveys and field measurements of noise. We know that there are individual differences to noise exposure so that some people are hardly ever affected and others are easily bothered. Other things being equal, there is a dose-response relationship: the noisier the environment is, the larger the percentage of reported annoyance.

Other things are rarely equal, however, and a number of factors have been found to moderate the noise exposure annoyance/attitude relation. These include the intermittency of the noise, the predictability of the noise, the perceived extent to which the hearer can control the source of the noise, the extent to which the noise is deemed necessary for an important purpose, the amount of noise to which comparison people are exposed, and the relationship of the hearer to the noise. These contextual variables can moderate or exacerbate the reported reactions to the noise so as to disrupt the apparent

connection between the amount of noise and the reported annoyance. A faucet erratically dripping at night at a level of 55 dB or less may generate more annoyance than a constant stream of traffic at 90 dB.

Behavioral effects of noise consist of those cases in which performance of tasks or ongoing behavior is modified by environmental noise. In some cases, particularly tasks involving tedium and vigilance, noise may not affect or may even enhance performance. In many tasks studied, in the short run, noise has little effect on performance. What decrements do occur show rapid adaptation. In cases of task overload (i.e., where an individual is working at more than one task at a time or where the task is so demanding that the individual can not perform it at a high level, noise will further degrade performance).

Most of the studies of the effects of noise on performance have examined such tasks as repetitive mechanical operations, motor skills, simple clerical tasks, or even proofreading. Few studies have examined the effects of noise upon more complex activities, for example, reading comprehension, the creation of prose, moderately complicated computations, or ones involving judgments or the weighing of alternatives.

There is some recent evidence that decisions made under noisy conditions may show more dependence on the use of short-cutting heuristics than those made under relatively quiet conditions. Although it seems likely that contextual factors would moderate the noise-performance link, in a manner analogous to the way in which they moderate the noise-annoyance link, more evidence is needed to establish this conjecture firmly, particularly for complex tasks. It should be noted that even in cases where behavioral effects have habituated, there may still be decremental aftereffects, that is, performance deficits that occur after the cessation of the noise or after a change in the environment.

The **psychological effects of noise** are not evenly distributed in the population. For some effects, there are different risks for parts of the population at different developmental stages. It has been documented that noise can disrupt the ability of children in the primary grades to acquire reading skills. It is not known whether the disruption is different for children who are learning impaired or whether subsets of the elderly, such as those with impaired cognitive function attributable to diseases such as Alzheimer's, would be differentially disrupted by noise.

Recommendations

Physiological Effects

A national strategy for identifying non-auditory health effects of noise and for addressing noise control issues is critical for preventing unnecessary adverse consequences of overexposure to noise in the future.

Based on the findings of research from many countries, noise can be conceived of as a physiological and psychological stressor. If sufficiently intense, it can elicit stress reactions, including those related to the pituitary-hypothalamic and the sympathetic/adrenocortical and adrenomedullary axes. Other stress-related hormonal, electrolyte and enzymatic changes have been elicited as well. Although certainly not unequivocal, evidence from a large number of epidemiological studies suggest that prolonged exposure to noise levels found in many factories and in extreme community environments can increase blood pressure. Animal-model research studies, in the main, support such evidence. Laboratory studies using human subjects, indicate that, when noise is perceived as uncontrollable, blood pressure effects are exacerbated.

Recently, strong evidence has accrued concerning plausible biological mechanisms for noise effects, many of which are also seen in typical stress reactions. The most promising contemporary model involves magnesium deficiency.

It is well established that hypertension is a major risk factor for the leading causes of death in western society, ischemic heart disease, myocardial infarction and stroke. If, indeed, only a small segment of the exposed population is adversely affected by noise, then the public health implications are far reaching and serious. Although at this time the best estimates for relative risk appear to be modest (between 1.2 and 1.5), the absolute number of people at risk might be extremely high because of the large population chronically exposed to excessive noise. Despite considerable associative evidence, there is still no consensus among experts in this country that noise *directly causes* blood pressure elevations and other effects. It is generally agreed, however, that causality must be demonstrated within the framework of human epidemiologic research in order to gain general acceptance.

We therefore strongly recommend that, as an early initiative, adequately large-scale epidemiological research be funded in the area of noise-induced hypertension. An undertaking of this sort

could serve as a platform for international collaboration and shared governmental support.

- Such studies must employ longitudinal prospective designs to track noise-induced changes as subjects are exposed to the noise over time.
- Sample size must be large enough to detect small differences between exposed and nonexposed groups.
- There must be precise measurement of individual exposures, using a standardized noise metric and a precise specification of outcome variables to avoid smearing of effects through ambiguous measurement.
- The many confounders, including, but not limited to age, smoking, body mass index, alcohol intake, salt intake, family history of hypertension and myocardial infarction, physical activity, marital status, and employment status must be taken into account and controlled.
- Powerful and appropriate statistical methods should be employed.
- It has been estimated that, assuming a relative risk of 1.5 for noise-induced hypertension, a study involving about 6,000 subjects and lasting no fewer than 5 years would be required to answer the basic question of causality. Although difficult in terms of cost and finding the appropriate population to study, "... further studies based on insufficient resources might be wasted efforts."

Establishing causality is a crucial first step in understanding how noise affects health. There are several other areas that must be considered as well:

- The magnitude of risk, under a range of exposures and circumstances, must be understood. Additionally, noise may not act directly as a stressor, independent of much more complex and individual factors. Indeed, many observers have advanced the notion that noise affects human health only after it has been cognitively processed and appraised as a stressor.
- The groups most at risk must be identified; they may require protection on a priority basis.
- The mechanisms underlying non-auditory health effects must be explored to suggest efficient ways of protecting against harm.
- The interaction effects of noise and other noxious agents must also be explored.
- Protective methods and protocols must be established and priced, based partially on information about groups at risk and underlying mechanisms.
- Based on solid information about relative risk and the cost of protection, cost-benefit analyses must be undertaken, specifically considering non-auditory health effects, to ensure that, if legislation offering protection is proposed and enacted, it is fair and equitable.

Historically, carefully controlled human and animal laboratory studies have proven to be extremely useful for discovering and elaborating health effects not easily determined through epidemiological designs.

Each of the above issue areas is important to our understanding of the potential threat noise poses to the health and welfare of the American public. We therefore recommend that epidemiological, human laboratory and animal-model research be adequately supported using a coordinated, integrated strategy.

Psychological Effects

The following issues should be prioritized for initial and further study:

- The noise and performance literature has focused on industry and simple clerical tasks. As the work force moves to more complex activities, there is a need for studies of the effects of noise on more complex tasks, those typical of the modern workplace. Obviously, even a slight, but widespread decrement in the workplace productivity, can further jeopardize this county's competitive position.
- There are documented reports showing that prolonged noise exposure, either at school or at home (or both), interfere with children's reading acquisition skills. There should be a prospective exploration of mechanisms underlying noise-related learning problems such as delays in language acquisition and identification of attentional deficits.
- It is well established that the controllability of noise is an important factor in influencing the responses to noise and it is reasonable to assume that control may be a central explanatory mechanism in some of the studies showing the effects of noise. It should also be noted

that the effects of noise persist after the noise has ceased and that these effects are found in the laboratory as well as field studies on learning behavior.

- In most situations, stress accumulates across difference stressors. It would be valuable to examine whether noise lowers peoples' thresholds for reactivity to other stressors.
- In non-auditory health effects research, noise is usually conceptualized as a direct-acting stressor. The complex relationship between psychological and physiological variables must be examined more closely. This should provide crucial information about the mechanisms underlying physiological outcomes. People exposed to noise often respond with annoyance and other states of negative affect. These states appear to activate the same sympathetic nervous system and cardiovascular control processes as those activated by noise and other stressors. All of these relationships are in urgent need of examination.
- The United States Environmental Protection Agency should be the focus of support, and coordination, with the possible involvement of other agencies. Ideally, one to three university-based national centers of excellence should be established to undertake large scale, interdisciplinary research activity into the non-auditory health effects of noise. These centers should also be responsible for training young investigators in noise research to furnish a national pool of expertise in this area. This would help our nation regain the initiative in this field.

WORKING GROUP II MEMBERS

Ernest A. Peterson, PhD - Chair
Codirector, Medical Computer Systems Laboratory
MCSL (D-55) - Trailer Annex 2
University of Miami School of Medicine
1800 NW 10th Avenue
Miami, FL 33136

Burton M. Altura, PhD
Professor of Physiology
SUNY Health Science Center at Brooklyn
Box 31
450 Clarkson Avenue
Brooklyn, NY 11203

Gary W. Evans, PhD
Professor
Program in Social Ecology
University of California, Irvine
Irvine, CA 92717

David C. Glass, PhD
Professor of Psychology and Psychiatry
Vice Provost for Research Pro Tem
SUNY at Stony Brook
Administration Building, Room 407
Stony Brook, NY 11794-1401

Jerome Singer, PhD
Chairman, Department of Medical Psychology
Uniformed Services University of the Health Sciences
4301 Jones Bridge Road
Bethesda, MD 20814-4799

Alice H. Suter, PhD
Consultant in Industrial Audiology and Community Noise
1657 River Dee Court
Cincinnati, OH 45230

Evelyn O. Talbott, DrPH
Associate Professor of Epidemiology
University of Pittsburgh
A544 Crabtree Hall
130 DeSoto Street
Pittsburgh, PA 15261

Shirley J. Thompson, PhD
Associate Professor
Department of Epidemiology and Biostatistics
School of Public Health
University of South Carolina
Columbia, SC 29208

WORKING GROUP III
SPEECH, SLEEP, AND COMMUNITY ANNOYANCE

Karl S. Pearsons - Chair

Introduction

Annoyance

Everyone agrees that noise can have a pronounced effect on speech communication, disturbance of sleep, and general annoyance in the community. An annual housing survey conducted in the 1980s indicated that 18% of the people were disturbed by road traffic noise. The difficulty is how the noise or effects are quantified and what are "acceptable" levels of noise or effects of the noise. Much research has gone into studying the various effects of noise, and many noise metrics have evolved over the years to quantify both the noise and its effects. Unfortunately, the multitude of noise metrics has compounded the problem. In the quest for the "best" noise metric, controversy arose and it became difficult to compare studies due to the differences in noise metrics. Metrics included A, B, C, D, and E levels, SIL, NC, NCA, PNC, SEL, CNEL, DNL, PNL, EPNL, CNR and a few different versions of loudness and loudness level. Of course, noise could also be reported in terms of its maximum, peak, average, energy average, or percentile level. The level exceeded a certain percentage of the time (e.g., L_1, L_{10}, L_{50}, L_{90}, or L_{99}). Then too, the noise could be reported in terms of its spectral components using fixed or proportional bandwidths.

Although the myriad of metrics still exists today, one metric, the day-night average level (DNL), has emerged as a descriptor of environmental noise for assessing community annoyance. This is in part due to the work of EPA in the 1970s in formulating "information on levels of environmental noise requisite to protect public health and welfare with an adequate margin of safety," commonly referred to as the *"Levels Document."* Basically, the metric uses an average daily level of noise and combines it with an average nighttime level of noise after adding 10 dB to the nighttime level to account for the assumed added sensitivity of people to noises occurring during nighttime hours. Although there is large variation among people, Schultz, in 1978, developed a relationship between the percent of people highly annoyed and this DNL metric. The relationship was based on a review of community surveys in which noise was assessed by community residents. The results were duplicated in a more recent analysis using more recent studies of community noise assessment. A distinction must be noted between annoyance and complaints. Certainly people that complain are annoyed, but a person may be annoyed and not complain for various reasons.

The relationship and metrics of both community response and noise are not perfect but they certainly provide a useful tool for community noise assessment. The method assumes that people's annoyance is based on the equal energy principle. That is, if one noise is twice as long as another, then it must be 3 dB less in level than the first to be equally annoying. Setting a limit of noise in terms of DNL does not preclude possible high levels of noise if the noises occur infrequently. Further, the metric does not account for the difference between noises of a given level in an urban setting versus noises of the same level in a rural setting where the background noise is much lower; nor does the noise metric account for non-acoustic influences which may affect people's assessment of the noise. These are some of the areas that need further

research. Hopefully, the eventual metrics will build on the current ones rather than replace them.

Speech

Ordinarily, if noise interferes with speech communication in the home, the noise is considered annoying and thus the assessment of speech communication disturbance is reflected in the reported annoyance of the intruding noise. Certain situations may be more critical or sensitive to speech interference. School classrooms or lecture halls, theaters, and churches are all examples of environments where speech communication is particularly critical. In these environments, a specific amount of speech interference may be less tolerable than in the residential environment. Also, in these environments, more people are affected by speech interference of a single speaker. An energy-averaged metric of noise such as L_{eq} may provide some information about the amount of interference of speech caused by steady noise, but it is difficult to assess the interference caused by time-varying noise. Then, too, measurement of the noise is only part of the equation. The level of the noise of speech is also important in determining the amount of interference. Detailed measurements of speech intelligibility special measures, such as Articulation Index or Speech Transmission Index, are required that include both noise and speech levels in their determination.

Sleep

Sleep disturbance, like *speech interference*, may also be included in people's reported annoyance of environmental noise. However, as with speech interference, certain environments are more critical or sensitive to sleep disturbance than in the residential situation. Hospitals or convalescent homes are examples of environments where sleep disturbance may produce effects other than annoyance. Unfortunately, sleep disturbance is not as well understood as speech interference. A recent review of sleep research indicates a great disparity in results found in the laboratory and that found in field situations. Anecdotes abound with examples of people's ability to sleep in extremely noisy situations, but at the other extreme, many people have difficulty sleeping even under quiet conditions. The DNL noise metric with its 10 dB nighttime penalty provides an incentive to reduce noise during nighttime.

It does appear that people are less likely to be awakened by steady noises than by intermittent ones. Thus, the equal energy type of noise metrics may not be the best to relate to sleep disturbance. Tests have shown, at least in laboratory situations, that the longer an intruding noise is present, the more likely a person is to awaken. Therefore, some measure that includes duration of the noise would appear to be appropriate. The amount that the intruding noise exceeds the steady background may also be a factor.

One disconcerting factor remains about sleep disturbance. We still don't know how awakening or sleep stage changes relate to long-term health effects. It may be that the annoyance created by sleep disturbance is the most appropriate measure after all.

Hopefully, this brief overview has provided some background to indicate areas of concern in speech and sleep disturbance and community annoyance.

Summary of Working Group Discussion

The working group met and discussed needs for noise-related issues in the areas of concern for the group. Many subjects were mentioned resulting in the following list of recommendations that represent a consensus of the group. In the short time available it was not possible to delve into all of the areas which are, or may be in the future, important to people at home, in the workplace or in some recreational environment. However, the group feels that many of the important concerns have been addressed in the recommendations below.

Recommendations

- Establish a central agency for collecting, disseminating, and interpreting research and findings in the noise sphere. This might be a resurrection of ONAC at EPA or a completely new agency.
- Establish a central agency to represent the public interest in environmental noise and its effects. Other agencies have goals that may conflict with the desire for a quiet environment. This agency would help to balance the various goals. The agency need not necessarily be the same as the one noted in #1.
- Day-night average sound level (DNL) is a widely applicable descriptor for environmental noise assessment and should be continued to be utilized. A widely accepted relationship between DNL and high annoyance has been found to be useful for the assessment of transportation noise in residential communities.

- Environmental noise exposures should be analyzed and disclosed at levels below those commonly utilized in current environmental practice (e.g., DNL 65 dBA). This is not to say that the acceptable limit that may be set partially by economic considerations needs to be changed, but only that additional information be provided to give a more complete description of the noise environment.
- Specialized noise descriptors should be utilized for important communication-critical environments. In locations such as schools or lecture halls where communication is important, descriptors of the noise environment other than DNL will provide additional information regarding the predicted intelligibility in the particular environment under consideration. Such measures might include Speech Interference Level, Articulation Index, or Speech Transmission Index.
- Specialized sleep disturbance descriptors may be needed to properly assess this potential. The relationship between noise and sleep disturbance is not well understood at this time. In particular, a large discrepancy exists between the results of laboratory and field studies. One conservative approach is to use results of laboratory information which predicts more sleep disturbance at a given level than results from field studies.
- There is a value for quiet (tranquillity) in itself which should be given due consideration. Some people find noises unacceptable in many settings even if they do not interfere with speech or sleep.
- Procedures should be established for assessing noise degradation in the environment. Although noise from new sources may be predicted, the amount that the new noise exceeds the previous noise environment needs slowly to be described in terms of the amount of degradation. Perhaps some guidelines for a limit need to be set to clarify when degradation has occurred.
- Current practice in impulse noise assessment needs review. Most of the information on the annoyance in residential settings has been based on steady noises or transient noises such as transportation noises which vary relatively little with time. The response to impulsive sounds such as associated with blasting or supersonic aircraft is currently predicted using C-weighted Day-Night Average Level (CDNL). Limitations of this method need further study.
- The following list of research needs was made by the working group. They have not been prioritized and do not necessarily represent an exhaustive list of research needs.
  1. Investigate sleep disturbance in the community under various conditions and the extent of habituation.
  2. Study the effect of time-varying events on speech interference.
  3. Develop a dose-response relationship for the annoyance of impulse noise.
  4. Assess annoyance at low noise levels.
  5. Assess annoyance for infrequent noise events in both urban and rural, sparsely inhabited environments.
  6. Assess annoyance with respect to domestic appliances and equipment.

WORKING GROUP III MEMBERS

Karl S. Pearsons, SM, Chair
Senior Scientist
BBN Systems and Technologies
21120 Vanowen Street
Canoga Park, CA 91303

James M. Fields, PhD
Independent Researcher
10407 Royal Road
Silver Spring, MD 20903

Jerome S. Lukas
Consultants in Engineering Acoustics
25 Drumm Street, Suite 202
San Francisco, CA 94111

George A. Luz, PhD
Supervisory Environmental Noise Consultant
U.S. Army Environment Hygiene Agency
Bio-Acoustics Division
Aberdeen Proving Ground, MD 21010

Fred Mintz, MS
Staff Consultant
United States Environmental Protection Agency
4601 North Park Avenue, #908
Chevy Chase, MD 20815

Robert A. Samis, MA, MRP
Robert A. Samis & Associates
11706 Smoketree Road
Potomac, MD 20854

WORKING GROUP IV
STATIONARY NOISE SOURCES

Robert D. Bruce - Chair

Introduction

Good morning colleagues from the Acoustical Society of America, the American Academy of Otolaryngology-Head & Neck Surgery, the American Speech-Language-Hearing Association, and the Institute of Noise Control Engineering. It is a pleasure to be with you today to discuss a problem of great importance which has not received consistent attention by any of the responsible parties. In my role as Chair of the Working Group on Stationary Noise Sources, I will share briefly with you some of the issues that our group will be discussing today.

First, a definition of Stationary Noise Sources may be in order. Actually, a more appropriate title might be "Non-consumer, Non-transportation Noise Sources." This category includes individual industrial machines and their components as well as complete operating facilities.

Objectives

The objectives of our working group are to answer the following two questions:

1. What should be the federal government's noise control policy with regard to these industrial types of sources?
2. What legislative strategy should be used to implement this policy?

Before answers can be developed for these objectives, it is necessary to understand why noise control is of interest. Our previous speakers have addressed three issues: (a) permanent hearing loss, (b) psychological and physiological effects, and (c) annoyance. From the perspective of the Members of Working Group IV, prevention of hearing loss of workers and reduction of annoyance to nearby residents are the primary reasons for controlling noise exposures.

As a child of 4 or 5 years of age, I was exposed to industry when my grandfather gave me a tour of the local cotton gin in our town in southeast Texas. I met a man without a left arm. When my grandfather told me that the man had lost his arm, I was confused. I remember trying to understand how you can lose your arm. I tried pulling my arm to see if it was removable, but it wasn't. Later I learned that the man's arm wasn't lost, it had been savagely removed by the cotton gin. He had received the industrial equivalent of a red badge of courage. This type of accident happened more often in the '50s and '60s than today because of unsafe equipment designs. Workers who were performing honorable services for their companies lost fingers, hands, arms, and sometimes legs as a result of their employment. Fellow workers and family members learned about safety as the injured workers shared their horrifying experiences.

More recently, I recall meeting a gentleman in a foundry in Alabama. He had lost one of the fingers on his left hand. I asked him how it happened. He took me over to a table saw and began to explain. At that moment, I noticed that the same finger on the right hand was also missing. I asked how he lost it. He replied that he cut it off showing someone how he had lost the finger on his left hand! Even with safer equipment, accidents still happen when workers are not properly trained or they are careless in their work habits.

In our modern society, we prevent most of these industrial accidents by careful attention to detail in the design and operation of machinery. Today, the worker's industrial red badge of courage is *silence*. Family and fellow employees of workers with noise-induced hearing loss do not learn about safe hearing protection practices because the hearing-impaired workers often do not talk about their handicap. We must prevent this continued loss of a major national resource!

Although there are federal regulations that limit the noise exposure of most of America's civilian and military workers, the level of protection provided by the regulations varies. In general, the regulations governing military employees' exposures to noise are more stringent than those covering the manufacturing industry employees, and the regulations covering construction workers and oil and gas workers are even more lenient. We will discuss the rationale behind such differences and recommend a potential course of action.

Limitations of the noise of stationary equipment is clearly in the purview of the original equipment manufacturer, the purchaser, and the affected parties, whether they be workers or a community. The need for regulations limiting noise emissions of industrial machinery will be discussed.

Previous efforts by industry to limit the noise of stationary equipment have been partially successful. In the late '60s, there were a few companies using the purchase order specification as a means of limiting the noise of machinery. By the mid '70s, the focus became obtaining reliable acoustical data on machinery. Even today, there is still some difficulty in obtaining this information. Although there are a few exceptions, most of the industrial community is generally floundering without national leadership in noise control.

Whereas the protection of employees' hearing from excessive noise exposure is best handled at the national level for stationary noise sources, it would appear that local and state government actions in the form of noise ordinances may be the first step in limiting community annoyance from industrial facilities. Naturally, this type of ordinance could still be supplemented by specific nuisance suits as a measure to redress claims of damage due to noise exposure.

In 1978, EPA sponsored a workshop focused on "Noise Technology Research Needs." Among the reported conclusions was the need for the federal government to coordinate research activities, collect and disseminate information, and support demonstration projects. We will discuss these needs.

Manufacturers of machinery in the United States sell their goods in the international market. Today, the European Common Market (ECM) has a gross national product (GNP) of about 25% more than the United States GNP. Most United States firms will want to sell their goods in the ECM. It is likely that all equipment that will be sold in the ECM will have to meet a stringent noise labeling requirement. Indeed, it may be necessary for the equipment to be measured in ECM-approved facilities.

To remain competitive and strong in this market, United States industry needs consistent leadership and direction at the national and international levels, as well as cooperation between the regulators and industry.

Working Group IV addressed the needs for a uniform hearing conservation program, labeling of products, assistance to state and local governments, research, noise emission regulations and other topics related to the protection of the hearing of our work force, and the competitiveness of our industry in foreign and domestic markets.

Summary of Working Group Discussion

Members of Working Group IV decided that all recommendations from the group would be unanimous. The discussions were focused primarily on the need for national leadership in noise control and the benefits that can be provided by such leadership. This national leadership is needed to ensure that workers no longer incur noise-induced hearing loss, to assist American industry in developing quieter products with appropriate labels that can be sold in the ECM and compete with ECM products domestically, to provide for coordination in noise research and education, and to create incentives for accomplishing noise control.

Recommendations

Working Group IV on Stationary Noise Sources recognizes that there is a need for United States industry to become more competitive in the international marketplace. Specifically, we believe that it will be possible to significantly improve the competitive position of American industry by offering quieter products for sale in the European Common Market and other international markets as well as in the domestic markets which currently compete with quieter ECM and Japanese products. In addition, these quieter products, when installed in

American workplaces, will achieve two major benefits: increased worker productivity by decreasing annoyance due to noise, and the reduction of health care costs through the elimination of noise-induced hearing loss to workers in the American workplace. All of the members of the Working Group IV support the following recommendations.

Uniform Hearing Conservation Program

- Apply uniform hearing conservation rules to all industries, all workers, all employees, and all employers. The Hearing Conservation Amendment issued by OSHA in 1983 can be used as a guideline.
- For existing plants, achieve compliance by engineering and administrative controls if TWA > 90 dBA. It is also desirable for existing plants to eventually achieve compliance with engineering or administrative controls down to a TWA (time-weighted average) of 85 dBA.
- For all new plants and for expansions of existing plants, achieve compliance with engineering or administrative controls for TWA's > 85 dBA.

Labeling

- Label all equipment that produces A-weighted sound levels greater than 75 dBA (free field) at one meter from the perimeter of the equipment.
- Develop a model measurement procedure that can be adapted by industry trade associations and working groups.
- Recommend that the measurement methodology for all specific equipment items be developed by industry and professional society consensus.
- Label product sound power in octave bands and/or A-weighted sound level at the operator's position.

Regulations

- Place no limits on noise emissions of industrial equipment.

State and Local

- Present no specific limits to state and local governments for limiting the noise of facilities. State and local governments can determine the levels that are acceptable to their communities.
- Support state and local governments by providing educational materials to assist in educating the public.

Coordination

- Establish and maintain a focal point for coordination of all federal activities in noise. This focal point is not necessarily within EPA.
- Provide funds to sponsor American representation on all appropriate International Standards Organization (ISO) standards working groups.

Research

- Emphasize studies dealing with noise generation mechanisms and noise control by design.
- Work with industries to develop demonstration projects.

Education

- Support undergraduate and graduate level topics on noise control in engineering and science programs.
- Develop public education documents and programs on industrial noise, its effects and control.
- Encourage companies to provide additional educational information on noise with their equipment literature.

Incentives

- Develop tax incentives to encourage the necessary investment to develop quieter products and workplaces.
- Establish a green label, similar to that in use in ECM countries, for recognizing products that meet environmental standards including quieter performance.

WORKING GROUP IV MEMBERS

Robert D. Bruce, EE - Chair
Principal Consultant
Collaboration in Science and Technology, Inc. (CSTI)
15835 Park Ten Place
Suite 105
Houston, TX 77084-5131

Wayne E. Bradley, BA
Supervisor, Noise Control Engineering
Stone & Webster Engineering Corporation
245 Summer Street
Boston, MA 02107

J. Alton Burks, ScD
Physical Scientist
U.S. Bureau of Mines
P.O. Box 18070
Pittsburgh, PA 15236

T. James DuBois
Supervisor, Maintenance, Engineering & Planning
Southern California Edison
2244 Walnut Grove
P.O. Box 800
Rosemead, CA 91770

Martin Hirschorn
President
Industrial Acoustics, Inc.
1160 Commerce Avenue
Bronx, NY 10462

Francis Kirschner, PhD
Soundcoat Co., Inc.
1 Burt Drive
Deer Park, NY 11729

Hsien-Sheng (Jason) Pei, MA
Digital Equipment Corporation
63 Woodbridge Road
Wayland, MA 01778

Marehalli G. Prasad, PhD
Director and Professor of Mechanical Engineering, Noise and Vibration Research Laboratory
Stevens Institute of Technology
Department of Mechanical Engineering
Hoboken, NJ 07030

WORKING GROUP V
MOBILE NOISE SOURCES

Nancy S. Timmerman - Chair

Introduction

This working group is concerned with mobile sources of noise. These sources can be divided into airborne and surface sources and are primarily transportation noise sources. Airborne sources include (a) jet aircraft, (b) propeller aircraft, (c) helicopters, and (d) supersonic aircraft. Surface sources include rail, trucks, buses, automobiles, and motorcycles.

The group will consider the nature of the noise: who receives it and how many are affected. It will consider the available noise control technology, look at changes in technology in the past 10 years, see what types of strategies have been used here and abroad, assess how effective they have been, and recommend a strategy for the 1990s for mobile noise sources.

Who receives the noise? At the present time, the total population of the United States is about 250 million. Of these, about half live in metropolitan areas with populations greater than 1 million. Most of these people will be affected by transportation noise, either as an operator, passenger, or observer.

How many are affected? Some recent Federal Aviation Administration (FAA) figures for air traffic show that there were 12,858,718 air carrier operations in 1990, 8,837,671 air taxi operations (commuter flights), and 39,169,795 general aviation operations. In the same year (1990), there were 457.9 billion passenger miles flown. That means that there were about 71,200 passenger miles/flight, or, with about 500 miles per flight, there are about 140 passengers per flight. In addition, there were 7,108 helicopters in 1985. For surface transportation, some similar figures show that of 183.5 million cars, trucks, and buses (1988), about 45.5 million were trucks. In addition, there were 1.924 trillion vehicle-miles traveled in 1987. There were 164.2 million licensed drivers in 1988, 8.34 billion public transit passengers carried in 1987, 4,831,000 transportation operators in 1988. There were 2.96 billion public vehicle miles traveled in 1987, and 22.1 million freight cars loaded in 1989. Thus, the problem is extensive.

The types of noise control technology that have been used are familiar to noise control engineers as being at the source, affecting the path, or at the receiver. For aircraft, some methods used have been quiet engines (source), noise abatement flight procedures (path), and sound insulation of homes and schools (receiver). For rail, vibration isolation has been applied to track (source), welded rail has been used (source), engines and other components have been quieted (source), cars have been insulated (path), and homes have been insulated, particularly overseas (receiver). For motor vehicles, again engines and other components have been quieted (source), the vehicle has been insulated (path), roadside noise barriers have been used (path), road surfaces have been improved (path), and homes have been insulated, again particularly overseas (receiver).

There have been technological changes in the past 10 years. Automotive functions are now computerized. Sophisticated measurement equipment is less expensive. Intensity measurements allow isolation of the noisy component. Noise cancellation techniques are available.

Some of the strategies that have been used to control mobile noise source are discussed here. At the federal level, the EPA set emissions standards

for locomotives and railcars, switcher locomotives, retarders, locomotive load cell test stands, car coupling, and motor carriers. The FAA set emissions standards for jet aircraft through its aircraft certification (Stage 2, Stage 3). The protection of the worker has been addressed by OSHA (Department of Labor). Operation and maintenance of equipment are handled by the Federal Railroad Association (Department of Transportation (DOT), Federal Aviation Administration (DOT), National Highway Traffic Safety Administration, and the Urban Mass Transit Authority (DOT). Barriers are used by the Federal Highway Administration (DOT). Sound insulation and zoning are strategies that are encouraged by the Federal Aviation Administration (DOT).

At the state and local level, strategies that have been used include (a) reducing speed limits, (b) time of day restrictions, (c) "quiet zones", (d) zoning, (e) land-use planning, (f) driver training for behavior modification, (g) testing vehicles in use, (h) aircraft flight procedures (with FAA), and (i) noise charges as a component of the aircraft landing fee.

The working group considered some of the following items: (a) the governmental agencies in which regulation, enforcement, and information reside and how they interact; (b) the constituency for transportation, noise control, and safety; (c) preemption and the local dilemma; and (d) other approaches including fees, financial aids, user charges, public information/labeling, training, and inspection and maintenance.

Summary of Working Group Discussion

A number of comments were received from people not present or not in the working group. These were first distributed to the members of the working group. The information included a letter from the Federal Aviation Administration, information from the Transportation Research Board, notes on transportation noise from the State of New Jersey, and a number of letters from Noral D. Stewart. In addition, notes from the introductory remarks and from R. Hickling were also distributed.

The first point of discussion included what noise sources would be considered and what receptors. It was agreed that the group on Stationary Noise Sources would address construction noise, and this was confirmed with that group. Noise sources included aircraft, rail, and motor vehicles. Power boats were briefly considered, but time did not permit a full discussion. Receptors included the operator, passenger, and observer (third party). Some effort was made to categorize approaches to the classes, but this was initially unsuccessful and was postponed.

Next, the group discussed whether an Office of Noise Abatement and Control (ONAC) should be re-established. There was general agreement. However, everyone had qualifiers. A list was prepared and is set forth under recommendations. In general, it was agreed that source noise control research should not be done in EPA, but that its noise office should monitor (and support) efforts of other agencies. The role of a citizens' advocate was discussed and considered to be important for aircraft and rail noise, but not for vehicular traffic. This point was made quite clear by members of the working group.

The group then turned its attention to each of the categories of transportation sources. The first source considered was *aircraft noise*. The efforts of the Federal Aviation Administration to date were discussed, and it was generally agreed that noticeable progress had been made in this area in the past. The new Airport Noise and Capacity Act of 1990 has continued this trend. The working group agreed that, owing to the phase-out of Stage 2 jet aircraft, noise impact will decrease initially, but it will increase with time after the year 2000. There was real concern that new (noisier) aircraft types will come online, and that no real progress will be made toward Stage 4. Particular types cited included prop-fans and supersonic aircraft. It was noted that source noise control was being worked on by NASA/Industry, and any advances would come from these sectors. Other issues were also addressed by this group, including the unique situation held by the United States that airport operators do not control aircraft in flight (the FAA preempts this), nor do they usually have flight track information, but they are responsible to the communities for noise control from their facilities. It was this discussion that led to the conclusion that an office of noise abatement and control in EPA should exist to provide a citizens' advocate position for aircraft noise.

The perennial problem of impact assessment was then discussed. It was agreed that, for many purposes, DNL (day-night average sound level) is an appropriate measure. However, in cases where there is a low ambient, or where a new noise is introduced, such as aircraft, it is not clear that the currently used criterion (65 dB) is adequate. This was addressed by Mr. Stewart in his report on a meeting at Nag's Head on September 16 and 17, 1991, which recommended "that methodology be

developed using DNL which (a) reflects acknowledged differences in community characteristics, including ambient noise levels, prior experience, and exposure to aircraft noise, climatic differences, and seasonal or temporal variations in noise; and (b) uses Single Event Noise levels as a supplement to DNL for better assessing impact on communication and sleep and for determining mitigating measures." The problem has, at this time, no clear solution.

Finally, within aircraft noise, the working group agreed with the research needs identified by the Transportation Research Board at their November 11-15, 1991 conference. These needs included (a) advanced technology for aircraft noise control, (b) supplementary metrics for the evaluation of aircraft noise impact, (c) aircraft noise model improvements, (d) helicopter noise model improvements, (e) assessment of sound insulation modification procedures, (f) testing of noise reduction resulting from sound insulation modifications, (g) information transfer to the community on the aircraft noise problem, and (h) building code and zoning ordinance development.

The discussion now turned to *rail noise*. Discussion of the current situation led the group to note that federal preemption was broader for rail yards than for airports. In particular, it was felt that the railroad noise preemption should be examined and be changed to permit local regulation of noise from sources that are actually local sources (e.g., noise from sources in railroad yards). The role of a citizens' advocate for a new office of noise abatement and control within EPA was felt desirable for rail because quieter equipment is not being as vigorously pursued as it was for aircraft. The biggest issue of concern to the group was high-speed rail, which was characterized as "very low-flying aircraft." Because these trains could potentially have substantial noise and vibration impact, there is a need to address this issue in the 1990s. Research needs identified by the Transportation Research Board included (a) "high-speed transportation noise and vibration design criteria study, (b) rail transportation ground vibration control technology evaluation, (c) rail corrugation and fastener stiffness study, (d) rail transportation vibration criteria study, and (e) bimodal corridor criteria for noise and vibration impact."

The final area considered was *road transportation*. A distinct difference was noted here as opposed to the other transportation sources. Because the large majority of these vehicles are not engaged in interstate commerce, it was deemed inappropriate for EPA to act as a consumers' advocate. In fact, some in the group felt strongly that regulation should be local. For road transportation that constitutes interstate commerce, such as heavy trucks, the federal regulations that apply were felt to be very lenient. At least one commentator felt that "had the EPA continued to require quieter and quieter trucks ..., we would have trucks that would be perhaps 65 dBA or less today." For heavy trucks, in-use controls would be left to the localities. This would require enforcement, which can be very effective (according to both local and international studies). A study by the New Jersey Department of Transportation shows that 5% to 8% of the truck population is louder than what is considered the average level for trucks by 5 dBA to 20 dBA. Enforcement would retain the gains achieved by quieter new products.

A need was also identified for unifying the national and international methods for measuring sound output from road vehicles. This would also enhance international competitiveness in an area where it is badly needed. Technical considerations included whether specifications should be based on tire noise or pavement noise, or perhaps on the power train. A concern was voiced about when the aerodynamic noise of the vehicle starts to predominate. Finally, it was agreed that manufacturers should demonstrate that noise reduction can be achieved without a reduction in performance. Improvements are needed in noise prediction for highways.

Recommendations

1. The group recommends that a noise office in EPA should exist.
   - It is suggested that a change be made in the title of the office responsible for noise activities (e.g., Office of Noise Abatement).
   - The agency should be non-adversarial, attempt to build consensus, and cooperate with other agencies.
   - In some cases, and in particular for aircraft noise, the agency should function as a citizen's advocate.
   - It should help foster international trade.
   - It should provide leadership (coordination).
   - It should help define impacts and guide criterion development.
   - It should be a data repository.
   - It should have limited regulatory powers.

- It should engage in product noise labeling.
- It should have highly qualified technical staff.

2. The reasons given to re-establish the noise office at EPA are:
   - To address growing public concern about noise,
   - To avoid conflicts of interest in other agencies (e.g., FAA),
   - To help re-establish local programs,
   - To disseminate new scientific and technological information,
   - To maintain and improve the quality of life, (e.g., tranquillity),
   - To disseminate noise information about the noise problem (public education), and
   - To promote responses to international product noise standards, thereby increasing U.S. international competitiveness.

3. In the area of aircraft noise, the group makes the following recommendations:
   - Provide more funding for source noise control at NASA.
   - Because noise impact from aircraft is neither well understood or well-defined, this area needs more study and could be a function of the noise office at EPA.
   - Source noise regulation should remain with the FAA.
   - Consider the need to amend Federal Aviation Regulation Part 36 limits to control impact after the year 2000.
   - The EPA office of noise abatement should take the role of a citizens' advocate.

4. In the area of rail and guided high-speed transportation, the group offers the following recommendations:
   - The DOT and railroad industry should focus on source noise control.
   - The office of noise abatement should focus on impact assessment and guidelines.
   - Local control of noise from railyards should be permitted.
   - Federal preemption should remain for source noise control for intercity and interstate rail.

5. In the area of highway transportation, the group makes the following recommendations:
   - Unify the regulation of new vehicles nationally and internationally.
   - Encourage the implementation of new quieting technologies into newly produced vehicles.

WORKING GROUP V MEMBERS

Nancy S. Timmerman, SM - Chair
President, Institute of Noise Control Engineering
Noise Abatement Supervisor
MASSPORT
Logan International Airport
East Boston, MA 02128

Domenick Billera, BSEE
Chairman of Transportation Research Board
Committee on Transportation,
Related Noises and Vibrations
New Jersey Department of Transportation
1035 Parkway Avenue, CN600
Trenton, NJ 08625

Larry Blackwood, MS, JD
Science Applications International Corporation
1215 N. Nelson
Arlington, VA 22201

Andrew S. Harris, MBA
Chairman, Harris Miller Miller & Hanson, Inc.
429 Marrett Road
Lexington, MA 02173

Robert Hickling, PhD
Associate Director for Applied Research
National Center for Physical Acoustics
Research Professor of Engineering
Coliseum Drive
University, MS 38677

Frederick M. Kessler, PhD
FMK Technology, Inc.
P.O. Box 168
Bound Brook, NJ 08805

Michael Staiano, PE
Staiano Engineering, Inc.
1923 Stanley Avenue
Rockville, MD 20851

David G. Stephens
Chief, Acoustics Division
NASA Langley Research Center, MS462
Hampton, VA 23665-5225

Eric Stusnick, PhD
Wyle Laboratories
2001 Jefferson Davis Highway
Suite 701
Arlington, VA 22202-3604

WORKING GROUP VI
CONSUMER NOISE SOURCES AND HEARING PROTECTION

Elliott H. Berger - Chair

Introduction

Because of our proclivity as a society for excitement, power, speed, and efficiency, we gravitate toward noisy leisure activities and tolerate or even unduly appreciate the noise generated by the equipment or machinery we use at work and play. Although sounds around us greatly influence our lives and affect our ability to communicate, the auditory fabric of our daily experience is often of secondary importance. The problem is exacerbated by the public's lack of general awareness of the hearing mechanism and how it can be damaged by loud sounds. Nevertheless, in recent years there does appear to be a growing concern about the sea of noise in which we live.

Working Group VI was tasked with examining a particular aspect of the noise problem, those devices primarily categorized as consumer products. The Working Group also examined issues related to products designed for personal protection from noise, namely, hearing protection devices.

Noise exposures resulting from use of consumer products may arise from choice (e.g., listening to music) or because of hobbies, household maintenance and chores, and other non-occupational activities. The sources range from ones that are simply annoying (e.g., fans and air conditioners), to others that strongly interfere with communications (e.g., coffee grinders and vacuum cleaners), to those that pose a serious risk of hearing loss (e.g., recreational shooting).

An important component of any effort to prioritize a national response to noise arising from consumer products is data on their noise levels, and frequency and duration of use (i.e., the non-occupational noise dose experienced by a typical American). Few reports are available, and those that are, rely on scant data to estimate typical exposure durations (Schori & McGatha, 1978; Siervogel, Roche, Johnson, & Fairman, 1982; Simpson & Bruce, 1981; Weissler, Zerdy, & Revoile, 1974). Such information is required to determine whether loud sources of noise (e.g., power hand tools) are used frequently enough for the effective noise dose to become hazardous.

The following introductory remarks are organized to address specific categories of noisy products. A subsequent separate section presents the findings and recommendations of the Working Group, along with an accompanying tabular summary. The product categories are as follows:

1. Guns
2. Music reproduction and personal stereo systems
3. Equipment and appliances
   (a) Power tools and outdoor power equipment
   (b) Household appliances
   (c) Information technology equipment (ITE) (office and computer)
4. Toys
5. Hearing protection
6. Building spaces

Guns

Of all the noise sources to which we voluntarily expose ourselves, guns are unarguably the most hazardous and also one of the most prevalent, with an estimated 50 million Americans owning and using firearms. Guns are loud, typically creating

peak sound pressure levels (SPLs) of 150-170 dB. Although they can be quieted with sound suppressors ("silencers"), use of such controls is problematic because of federal law enforcement regulations (BATF, circa 1930) and technological feasibility.

Hearing protection should be worn by all shooters, but evidence indicates that from 15% to 40% of shooters still do not wear protection under certain conditions, and less than 1% wear hearing protection while hunting (Kramer, 1989, 1990).

Music Reproduction and Personal Stereo Systems

Much concern has been expressed about hearing damage from consumer music reproduction systems, particularly earphone-based or Walkman-type products (also called personal sound systems). The popular press has often decried the most flagrant of the reported measured sound levels (120-130 dB); such levels are the exception rather than the rule. Nevertheless, when music is listened to at elevated levels for prolonged periods on a regular basis, a risk of noise-induced hearing loss does exist. Review of a number of studies that have evaluated representative listening levels and usage patterns for personal sound systems indicates "concern is warranted for only those few listeners who prefer listening at maximum levels for extended periods of time" (Clark, 1991).

Unlike the other consumer devices for which excessive noise emission is usually an unwanted by-product, sound emission is the design function of a music system. Any method for limiting that emission directly affects the utility of the product and can adversely influence sound quality.

One approach towards consumer protection that has already been implemented in a limited manner includes educational and public-relations campaigns (EIA, 1991; Koss, 1991).

Equipment and Appliances

Users may desire quieter equipment and appliances, but awareness of the problem, uniform simplified noise ratings, demand for quieter products, and a willingness to pay for them have been lacking, or manufacturers would have already responded more vigorously. Although the Noise Control Act empowered the Environmental Protection Agency (EPA) to identify major noise sources that included any motorized or electronic equipment, few such sources were specified before the demise of the Office of Noise Abatement and Control (ONAC) (Shapiro, 1991). Since that time, the strongest impetus in this area has been the Europeans' sensitivity to environmental noise and their vigorous enforcement of noise pollution laws. To make products that are competitive in an international marketplace, U.S. manufacturers must mimic European designs that are perceived to have higher quality, at least in part because of their reduced sound levels (Lyon, 1990).

The design of quiet products (rather than after-the-fact noise control or regulation) requires a certain "infrastructure" that is only partly in place. Engineers must learn how to design quiet equipment, rather than applying noise controls as a band-aid solution, and incentives should be developed for manufacturers to design quieter products.

Power Tools and Outdoor Power Equipment

Equipment in this category generates sound levels from 85 dBA up to 115 dBA (chain saws), which is serious enough to cause a substantial risk of noise-induced hearing loss if exposures are of sufficient duration. One product in this category, lawn mowers, were declared by ONAC (before its demise) to be a significant noise source, but regulatory emissions standards were postponed in favor of a voluntary labeling program, which remains in effect today. Consumers, however, have shown little interest (Shapiro, 1991).

Equipment redesign is feasible for certain products in this category and technology is evolving. For example, today's lawn-mower engines are 3-4 dBA quieter than 5 years ago, and leaf blowers, a particularly noisy device (95-100 dBA), can be quieted with improved fans and housings. On the other hand, experience with (premature) regulatory limits on noise levels indicates potential problems. In Scandinavia where such limits have been set, the levels have been achieved by designing the equipment to run more slowly, but at the cost of impairing the ability of the machinery to perform its intended function. Once purchased, users are prone to circumvent these controls by speeding up the units for more efficient operation.

Household Appliances

Unlike power tools, household appliances rarely can be considered hazardous to the hearing, because the noise levels are substantially lower (generally less than 85 dBA). Even for the louder devices such as blenders, hair dryers, and carpet shampooers, whose noise levels average 90 dBA, the frequency and duration of exposure and hence

the noise dose is quite limited (Simpson & Bruce, 1981).

Information Technology Equipment (ITE Office and Computer Products)

Noise emissions from ITE are becoming increasingly prevalent as the computer age matures and pervades all aspects of society. The levels of noise exposure are rarely hazardous, but are likely to cause activity interference and annoyance. The incentives for product noise control are driven by international requirements, primarily stemming from European regulations that focus on ITE noise created in the workplace.

ITE has been evolving at a breakneck pace. For example, electromechanical calculators that generated sound levels above 90 dBA (Weissler et al., 1974) have been replaced by silent electronic models; the ubiquitous impact printers with their 70-dB noise levels now feature "quiet" modes and are being rapidly supplanted in the marketplace by laser and ink-jet technology; nuisance squeals from monochrome monitors are disappearing as the frequency of video scan rates is increased and color monitors become commonplace.

Mature international standards exist for the measurement of the noise of ITE that are suitable for use in the development of a labeling program. However, adoption of these standards in the United States has been limited, and reliable product noise information is seldom available.

Toys

Noisy toys have been part of childhood experience for years. As early as the 1960s, measurements and comments about the most hazardous, firecrackers and toy firearms, have appeared in the literature (Gjaevenes, 1967; Hodge & McCommons, 1966). With the advent of modern electronics, an even larger variety of noisy toys is available, many of them mimicking their adult counterparts (Suter, 1991). However, even simple commonly accepted toys such as a baby's squeeze doll can create sound levels over 110 dB if held sufficiently close to the ear (Fay, 1991). Extra caution is warranted for the toys creating the most hazardous of levels because the users (toddlers and children) cannot be expected to be able to discern what are aurally safe behaviors.

Hearing Protection

For many situations, one of the obvious solutions to the "noise problem" is the use of personal sound suppression, more commonly called *hearing protection*. Such devices come in a wide variety of types, from earplugs that fit in the ear canal to earmuffs with large cups that enclose the external ear.

When worn properly, hearing protection devices can effectively prevent noise-induced hearing loss and reduce annoyance that might otherwise arise from the use of noisy consumer products. However, utilization is low, because of lack of awareness of the benefits of, and consumer resistance towards, use of such products. For example, in a number of studies of school-age children, very low hearing-protector use rates of only 5 to 15% have been observed (Chermak & Peters-McCarthy, 1991; Lass et al., 1987; Lewis, 1989). Even in industrial arts classes where safety glasses were required by 100% of the instructors who were surveyed, only 19% required use of hearing protection (Plakke, 1985). The same studies have shown an increased purported willingness to wear hearing protection after the students have undergone educational programs, but no follow-up surveys of the actual efficacy of this approach have been reported.

Hearing protectors are labeled, as required by the EPA (1979), with a Noise Reduction Rating (NRR), but the NRRs are such a poor indicator of actual delivered protection that they must be derated by about 50% to even provide a rough guide of the protection that typical users can expect to obtain (Berger & Lindgren, 1992). For consumers, the principal value of NRRs is that the presence of the EPA label indicates the product was designed for noise exclusion and tested for that purpose.

The misleading nature of NRRs is an important issue that cannot be properly addressed until ONAC is resuscitated, or responsibility for hearing protector labeling is transferred to another federal agency.

Building Spaces

One of the more common complaints regarding environmental noise is noise in building spaces. The sound levels may be from the transmission of outside noise into a structure, excessive sound transmission or impact transmission between adjacent living spaces, or from the noise of fixed machinery (heating, ventilation, and air-conditioning equipment) within the building. In large part, known technology exists to resolve these problems, but it has not been implemented because of either cost considerations, lack of attention to the problem, and/or insufficient knowledge by the

building trades of the material and care required in the construction of suitably quiet spaces.

Another factor contributing to the problem is that although building codes incorporate specifications on parameters from electrical wiring to methods of egress, they in general lack requirements for specification of sound/vibration transmission metrics or control of the problem.

Recommendations

The Working Group recommendations are both general, applying to all consumer products, and specific for each of the categories.

General Recommendations

- The most efficient and effective means to respond to the societal noise problems created by noisy products is to create a centrally located federal agency tasked with noise abatement. The EPA is probably the best candidate for location of this agency because its allegiance is clear, namely protection of the public health and welfare.
- Many of the Working Group's specific recommendations pertain to labeling of products to warn and educate consumers, and to provide an incentive to manufacturers to develop quieter products. However, labeling will also impose a burden on manufacturers, especially those who produce a broad range of products that would be subject to testing. This burden may be inappropriate for certain classes of products whose noise emissions fall within a narrow range of nonhazardous levels.
- An important aspect of an effective labeling program is the education of the general public with regard to noise and hearing loss. For detailed recommendations in this regard see the report of Working Group VII.
- Data on the sound levels produced by noisy consumer products are insufficient to determine noise hazard. Therefore, dosimetry studies on the nonoccupational noise exposure of typical American adults and children should be obtained to ascertain the noise exposure that results from use of common consumer products.

Specific Recommendations

The specific recommendations of the Working Group are summarized in Table 1. The following notes pertain to Table 1.

	METHOD OF REMEDIATION					
	Noise Hazard Labels	Sound Rating Labels	Noise Limit	Feasibility Demonstrations	Standards Development	Engineering Education
1. Guns	●					
2. Music reproduction equipment	●			●	●	
3. Equipment & appliances						
a. Power tools & Outdoor equipment	●	●		●		●
b. Household appliances		●		●		●
c. Information technology		●				●
4. Toys	●	●	●		●	●
5. Hearing protection		●			●	
6. Building spaces		●			●	

Table 1
Noisy consumer products and hearing protection, and methods of remediation.

- ***Noise-hazard label.*** A noise-hazard label should be provided for products that produce sound that is potentially dangerous to the operator. The purpose of this label is to warn the consumer about the hazards of the product and the actions they should take, such as wearing hearing protection or limiting exposure.

  The determination should be based on a standardized measurement procedure undertaken by an accredited laboratory or consulting firm. The accreditation should be provided by an impartial, independent organization such as is now available under the Department of Commerce, National Institute of Standards and Technology, National Voluntary Laboratory Accreditation Program (NVLAP). Initially, the label should be applied to a class of products (e.g., chain saws), and then potentially to only those models within a class that exceed a limit established for the entire class. The label should be a graphic or icon with a minimum of verbiage affixed to the packaging and/or the item itself, and to its instructions in a readily visible manner. Labels for classes of products should either be "warning" or "caution" labels depending upon the severity of the noise levels.
- ***Sound-rating label.*** A sound-rating label should be provided for products that produce sound that is hazardous, annoying, or interferes with communications. The purpose of this label is to educate the public about the noise levels of products they purchase and give them the ability to make buying decisions that would include product noise levels as one of their purchasing criteria. This will provide an incentive for manufacturers to create quieter products.

  The rating should be a sound pressure level measured at an effective user position under standardized conditions (operator-ear position or bystander position as appropriate to the equipment being rated). Measurements should be undertaken by an accredited (preferably NVLAP) laboratory or consulting firm. The label should be affixed to the product packaging and/or the item itself, and to its instructions, in a readily visible manner. The label should be a uniform graphic highlighting the noise rating number and consistent with any noise hazard or other EPA-required label.

  For *hearing protectors*, the label should consist of a noise reduction rating (NRR), like the currently used label. However, unlike existing labeled data, the measurement of the hearing protector attenuation should be made in a manner to provide a useful indicator of actual field performance.

  For *building spaces*, the "labels" should consist of interior sound isolation values, interior sound levels transmitted from outside the building to interior spaces, and interior sound levels produced by building mechanical equipment. The purpose of these data is to characterize the acoustical integrity of the structures so that buyers can make informed choices.

  All sound-rating/noise reduction labels should include an indication of the range of values for other products in the same class as well as a statement of the expected precision of the rating so that buyers are not mislead into believing that small, statistically or practically insignificant differences are important. The precision statement should be of the form, "differences of less than x dB are not significant when comparing rated values."
- ***Noise limits.*** Regulated noise limits should be promulgated for *only* those selected products for which noise hazard exists and users may be incapable of a conscious decision regarding safe use of the product (i.e., dangerously noisy products designed for toddlers and children).
- ***Feasibility demonstration.*** A government noise office should become involved in assessing available technology to reduce the noise levels of the products specified in Table 1. This assessment should consist of determining if feasible controls are available, developing new controls if possible, and demonstrating the effectiveness of those controls. The quieted devices should be evaluated not only for their noise output, but also for their ability to perform their original intended design functions in an acceptable manner with the noise controls and/or redesign in place.
- ***Standards development.*** ONAC should support the development of consensus standards, where needed, for testing and certification for noise-hazard, sound-rating, and noise-reduction labels. These standards should be consistent with international consensus standards to be effective in promoting American competitiveness in world trade. ONAC's

support should consist of funding participation on national and international technical standards committees by independent technical experts and/or ONAC technical staff.

For building spaces, the agency efforts should consist of the development and dissemination of a model building code that cities and towns can use to regulate construction to provide a quieter environment.

- ***Engineering education.*** Working design engineers and those still in school need to understand how noise is produced by various mechanisms in a machine and how the noise can be modified. Financial support for university design courses that include noise reduction is needed. Technical information and publications should be collected, including case studies, for the development of course materials. The eventual outcome of these efforts would be textbooks, audio and video demonstrations, and other materials to assist educators in developing noise-control engineering curricula.

Conclusions

Americans are routinely exposed to a wide variety of consumer products that generate noise levels ranging from the moderately annoying to the seriously hazardous. This Working Group has identified the principal issues that must be addressed and has provided specific recommendations to mitigate noise and to promote accurate labeling, more widespread utilization, and effective implementation of personal hearing protection devices.

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WORKING GROUP VI MEMBERS

Elliott H. Berger, MS - Chair
Manager, Acoustical Engineering
Cabot Safety Corporation
7911 Zionsville Road
Indianapolis, IN 46268-1657

Dennis Driscoll, MS
President and Principal Consultant
Associates in Acoustics
Suite 447
14900 Landmark Blvd.
Dallas, TX 75240-4634

Thomas M. Disch, MS
Senior Acoustical Engineer
Briggs & Stratton Corporation
Engine Applications Center
P.O. Box 702
Milwaukee, WI 53201-0702

Lyle F. Luttrell, PE
Associate and Site Manager
Amador Corporation
New Brighton Laboratory
Suite 103
1775 Old Highway Eight
St. Paul, MN 55112

Richard H. Lyon, PhD
Professor, Massachusetts Institute of Technology
Room 3-366
77 Massachusetts Avenue
Cambridge, MA 02139

Daniel Queen
Daniel Queen Associates
239 W. 23rd Street
New York, NY 10011

Gregory C. Tocci, MS
President, Cavanaugh Tocci Associates
327F Boston Post Road
Sudbury, MA 01776

WORKING GROUP VII
PUBLIC INFORMATION AND EDUCATION

Julia Doswell Royster - Chair

Introduction

There is wide agreement that the public needs more information about noise—its effects and its control. The need for educational efforts is clearly documented, especially for school children. Florentine (1990), in her presentation to the NIH Consensus Development Conference on Noise and Hearing (see Appendix I), summarized numerous investigations of the knowledge and behaviors of junior high and high-school students and their teachers regarding the effects of noise and how to prevent them. Every study found deficiencies in knowledge. Frager and Kahn's survey of health textbooks used in schools shows that students lack appropriate content concerning hearing and the effects of noise (Frager & Kahn, 1988).

Adults also lack knowledge about noise and hearing. Educators in occupational hearing conservation programs know that many noise-exposed employees have gaps in their understanding of how noise-induced hearing loss happens and how to prevent it. Most of the materials currently available on preventing noise-induced hearing loss come from occupational hearing conservation programs. Although the basic facts about the effects of noise are the same regardless of the noise source, these occupationally oriented materials are often too specific to OSHA requirements to be very useful in non-occupational contexts.

Occupational hearing conservation program experiences also tell us that providing information is not enough. Motivation is required before people start protecting themselves from noise.

I will briefly review past efforts toward public education as well as the recommendations of previous working group documents.

The Noise Control Act of 1972 and the Quiet Communities Act of 1978 contained two relevant provisions:

- labeling of products that emit noise capable of adversely affecting public health and products for reducing noise, and
- educational materials and technical assistance programs to support state and local noise abatement programs.

The useful school curricula, written materials, pamphlets, and booklets concerning noise and its effects which the Environmental Protection Agency (EPA) produced before its demise are no longer available.

Labeling in itself is informational, not educational. There is abundant evidence that the presence of a label, even if it is heeded by the product user, will not be sufficient to promote protective behaviors unless the individual has received other background education and specific training in how to carry out protective actions. For example, even if people are induced to attempt to wear hearing protection devices, they are unlikely to achieve sufficient attenuation without demonstration and preferably guided practice in the proper way to use earplugs or earmuffs.

Several recommendations relevant to public information and education were contained in the report, *NIOSH Proposed National Strategy for the*

Prevention of Noise-Induced Hearing Loss, even though this document focused exclusively on occupational hearing loss. The section on information dissemination included these strategies:

- Establish a central clearinghouse for collecting and distributing information about noise control and hearing conservation.
- Inform the public of the need to protect hearing.
- Develop educational programs and promote existing programs in primary and secondary schools and in universities ... about sound, its hazards, and self-protection.

The Consensus Statement from the NIH Consensus Development Conference on Noise and Hearing contained numerous strategies for the prevention of noise-induced hearing loss. Selected recommendations relevant to public education included:

- Target educational programs toward children, parents, hobby groups, public role models, and professionals in influential positions.
- Provide guidance and product noise emission labeling for consumers to assist them in purchasing quieter devices and reducing their noise exposures.
- Make hearing protection devices more widely available to the public and supplying comprehensive instructions for their proper use.
- Make basic audiometric evaluations and counseling more widely available to detect early noise-induced hearing loss.
- Enforce existing regulations for consumer product noise labeling.
- Re-establish a federal agency coordinating committee for noise issues.
- Develop public awareness through high visibility media campaigns.
- Add prevention of noise-induced hearing loss to the health curricula in public schools.
- Make self-education materials available to adults.

The report *Fighting Noise in the 1990s* from the Organization for Economic Co-operation and Development (1991) summarized characteristics of effective educational strategies based on an examination of efforts already undertaken in several countries. The authors concluded that public education campaigns are essential, but that they are more effective if they are *ongoing* rather than *sporadic*, *specific in scope* rather than *general*, and *local* rather than *national*. Effective educational efforts have been accomplished by private or nonprofit associations as well as by local governments or national campaigns.

The media information currently available to the public in the United States usually focuses on noise-induced hearing loss, excluding annoyance and other effects of noise. Unfortunately, this media coverage is typically sensational in nature. The risk of NIHL is often exaggerated because of an emphasis on noise levels of various activities without any consideration of total noise exposures (e.g., the duration of noisy activities and the frequency of their repetition). Media articles are also aimed largely at adults, especially at parents concerning the music-related sound exposures of their adolescent children. To illustrate the nature of misinformation directed at the public, a recent factual cartoon block on the front page of a nationally distributed newspaper stated that noise damages the eardrums (rather than the inner ear), implied that attending a symphony orchestra concert could cause hearing damage, and listed decibel levels that were probably peak sound pressure levels rather than representative A-weighted sound levels.

Educational efforts related to hearing could benefit from considering the recent advances in models of health promotion, as illustrated by campaigns for the prevention of smoking, cancer, and AIDS, as well as campaigns to promote recycling behavior. We will fail to affect people if we concentrate exclusively on factual knowledge or beliefs. To influence people, we must affect their attitudes, intentions, and behaviors. Behaviors are affected by constraints and consequences, such as the presence of bad side effects (discomfort and ridicule for wearing HPDs) or the lack of any immediate payback (because avoidance of noise-induced hearing loss is in the distant future). Social learning theory emphasizes the importance of peers and role models in determining behavior. New ecologic interventions in health promotion therefore aim not only at the individual, but at the social environment and the community to introduce support mechanisms which will encourage and maintain the desired behaviors.

For example, Kramer reports that the percentage of competition marksmen who wear hearing protection devices has increased dramatically in recent years. Factors contributing to this behavior change include the publication of information about

gunfire noise exposures and the resulting hearing losses by shooting publications and associations, personal experience of the communication problems suffered by old-timers who did not protect their hearing, the convenient availability of hearing protection devices at gun shops, peer modeling as shooters began wearing earplugs and earmuffs, and peer pressure and reinforcement as hearing protector use became the norm.

Working Group VII used the recommendations of the recently published summary documents together with additional current information as a basis for outlining the best approaches to educational efforts. Education is essential if other preventive strategies are to succeed. Warning labels or product ratings are of little benefit unless the public is taught their meaning and motivated to use them. Hearing protection devices are not helpful unless people are trained to use them properly and motivated to actually do so. Even regulatory approaches such as community ordinances work far better when the public is informed. Only an informed public can create a demand for quieter products and environments. In short, providing education and information is essential, but only if it is meaningful, relevant, and practical for the recipients.

Summary of Working Group Discussion

The members of Working Group VII supported the recommendations of past summary documents as outlined in the Chair's introduction. Members discussed ways to make the desired messages most appealing and most effective through "message framing" or social marketing approaches. However, even with the best message presentation, some groups (e.g., adolescents, farmers, and low-income adults) will be hard to reach and affect. Video tapes, not written materials, are probably the best medium for educating today's public.

It is desirable to start early to influence young children to value a quiet auditory environment and to appreciate their hearing. Preschool children might be reached directly through television shows similar to Sesame Street or cartoons. An indirect method to reach young children might be through the healthcare providers who can affect their parents. Maternal education is important, and efforts should be coordinated with existing programs such as Women, Infants, and Children (WIC) and well baby clinics.

Once children reach school age, the school system provides an opportunity to reach them if excellent, interesting curricula can be developed and provided to teachers. Moreover, if children take information home with them from school, they may affect their parents as well. One excellent opportunity to educate children about their hearing is through hearing screening tests which are given in most schools. In high school, consumer affairs courses could easily cover how to select quieter appliances and tools, and how to determine whether an apartment or home will be annoyingly noisy.

Popular notions that equate noisier products with greater power need to be overcome. It was suggested that truth-in-advertising might require TV or radio advertisements of noisy products to reproduce their sound at full volume to demonstrate the interference with communication.

The working group members discussed the human factors literature on warning labels. There was general agreement that labels of the simple warning variety are not very effective, as many people ignore them. Even for people who do heed them, labels of this sort would not contain enough information to discriminate between noise sources that are hazardous in a single use versus those that are hazardous only in long-term repeated use. Those people who can be influenced by a warning label to try to wear protective earplugs still need additional training in how to do so before they would achieve significant protection.

Rather than warning labels, the working group members favored noise emission rating labels which would assist consumers in choosing quieter products (e.g., chain saws, lawn equipment, or appliances). Consumers are experienced in using energy consumption rating labels for home appliances as well as auto mileage ratings. They could easily learn to use noise emission rating labels to select quieter products.

Recommendations

Working Group VII strongly supports federal government involvement in educating the public about noise.

Target groups for such education include:

- preschool children,
- school-age children and youth,
- college and professional students,
- adult citizens and consumers,
- practitioners in influential professions, and
- specific groups at risk.

The types of messages that educational efforts should deliver include the following:

- A quiet environment contributes to good quality of life.
- Noise can cause annoyance, stress, and interference with activities, communication, and sleep.
- Noise exposure can cause permanent noise-induced hearing loss which significantly degrades one's quality of life.
- When high noise exposure is unavoidable, noise-induced hearing loss is preventable through protective behaviors.

In communicating the messages listed above, educational efforts should focus on:

- the benefits of protective actions rather than the negative consequences of inaction (approach rather than avoidance);
- specific actions to take; and
- social reinforcement of desired behaviors.

To illustrate the types of educational efforts that the working group members favor, several examples are listed below:

- Develop interesting curricula for primary and secondary school educators, test the effectiveness of these curricula, teach the use of these curricula to teachers, and integrate these curricula into existing courses on health and consumer affairs.
- Develop curricula for professional training programs in such disciplines as medicine, architecture, and engineering.
- Develop noise emission ratings to enable consumers to select quieter products, and educate consumers about how to use these ratings.
- Develop videos and make them widely available to health clinics, doctors' waiting rooms, school libraries, public libraries, hobby interest groups (woodworkers), commercial video rental enterprises, drug stores, etc.
- Provide technical assistance for local citizens attempting to create or improve noise ordinances.
- Develop a clearinghouse to share information and advertise the availability of this service.
- Promote widely available hearing tests as a public educational and motivational tool in schools and clinics.
- Develop media campaigns using an identifiable visual symbol to heighten public awareness of noise as an environmental pollutant and hearing hazard.

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WORKING GROUP VII MEMBERS

Julia Doswell Royster, PhD - Chair
President
Environmental Noise Consultants, Inc.
P.O. Box 30698
Raleigh, NC 27622-0698

Kenneth Andrew, PhD
Vocational - Technology Educator
Department of Industrial, Technological, & Occupational Education
J.M. Patterson Building, Room 3216
University of Maryland
College Park, MD 20742

David DeJoy, PhD
Associate Professor and Department Head
Department of Health Promotion and Behavior
Stageman Hall, Room 221
University of Georgia
Athens, GA 30602

William L. Kramer, PhD
Associate Professor
Speech Pathology and Audiology Department
Ball State University
Muncie, IN 47306

James E. Lankford, PhD
Dean of the College of Professional Studies
Northern Illinois University
DeKalb, IL 60115

George Winzer
Principal Consultant
Winzer Associates
P.O. Box 5117
Rockville, MD 20855

Charles Woodford, PhD
Professor
Department of Speech Pathology and Audiology
805 Allen Hall
West Virginia University
Morgantown, WV 26506

WORKING GROUP VIII
STATE AND LOCAL STRATEGIES

Clifford R. Bragdon - Chair

Introduction

The primary strategy used by state and local governments for addressing the control of environmental noise has been the regulatory approach. This has involved establishing enabling authority at the state level along with noise control legislation, and enacting ordinances at the local level.

Historically local governments were the first political entities to initiate any type of noise legislation in the United States (Bragdon, 1971). Initially they primarily dealt with disturbance of the peace issues. Such laws contained nuisance type language concerned with street vendors, similar to the City of Boston law (enacted 1850). In the early phase of regulatory history, these laws contained only general language where noise was not quantified (e.g., noise was defined as that which is unreasonably loud, disturbing, or unnecessary) (Bragdon, 1980).

Initial efforts at regulating noise were minimal and it is estimated that during the 1930s there were only 20 municipalities with regulations in place. Table 1 provides an historical description of municipal noise legislation and the major influences. It was with the publication of *City Noise* in 1930 by the New York City Department of Public Health that noise sources were first measured (in conjunction with Bell Laboratories). Their report documented the sources, levels, and community response to this public health concern (Noise Abatement Commission, 1930). Many of their findings are similar to conditions found in urban areas today. Road noise levels for vehicles was first addressed by the city of Memphis, but it was not until 1948 that any national model ordinance was actually written. Land-use controls through the use of zoning as a police power first appeared in 1955, when Chicago amended their zoning ordinance incorporating performance standards for noise. Up to the early 1970s, there were less than 60 municipalities with legislation.

The establishment of the Environmental Protection Agency (EPA) and the passage of both the Noise Control Act followed later by the Quiet Communities Act, provided the primary impetus for state and local legislation (Bragdon, 1978). Both National Institute of Municipal Law Officers (NIMLO) and EPA developed model noise ordinances as guidelines to governments. EPA technical assistance programs were also initiated. By 1980 there were 2,100 laws in place, compared to less than 100 the previous decade.

The termination of funding, initiated by the Office of Management and Budget and approved by Congress, had a negative impact on both local and state government noise-related activity (Shapiro, 1991). Based on a recently conducted environmental legislation questionnaire, it appears that there has been a leveling-off condition (Table 1) in the passage of new noise laws (Bragdon, 1992).

More significant than the initiation of noise legislation has been the general decline in noise control programs established to implement these laws (Soporowski, 1990). Table 2 summarizes the state and municipal noise regulations and programs over seven decades. At the height of the EPA Office of Noise Abatement and Control activity, there were approximately 205 noise programs with specific budgets out of the 2,100 laws enacted (0.976%). However this does not mean other resources such as police, health, planning and zoning functions of government were

Period (Decade)	Municipal Noise Regulation (Estimated)	Historical Influences - Primary
1930 - 1939	20	City Noise: 1930 New York City Department of Health Motor Vehicle Code: 1938 Memphis Tennessee
1940 - 1949	25	NIMLO Model Ordinance: 1948 National Institute of Municipal Law Officers
1950 - 1959	35	Performance Zoning Ordinance: Chicago 1955, Armour Research Foundation
1960 - 1969	55	Motor Vehicle Code: California - 1967 California Department of Highway Patrol
1970 - 1979	2100	Municipal Noise Ordinances: Chicago Boulder, Inglewood, NIMLO Model Ordinance: 1970 EPA Noise Control Act and Model Ordinance
1980 - 1989	2400	Elimination of EPA, Office of Noise Abatement and Control - Technical Assistance Program - 1982 FAA: Part 150; Comprehensive Planning: States
1990 -	2620	??????

Note: Results of Clifford R. Bragdon survey through December, 1991 (in process)

Table 1
Evolution of Municipal Noise Control Regulations: Historical Influences

Decade	Municipal		State	
	Regulations	Budgeted Programs	Regulations	Budgeted Programs
1930	20	1	0	0
1940	25	3	0	0
1950	35	5	0	0
1960	55	10	2	2
1970	2100	205	27	21
1980	2400	93	27	8
1990	2700	76	26	7

Source: Clifford R. Bragdon survey (in process)

Table 2
State and Municipal Noise Regulations/Programs

not utilized to enforce these noise laws on a limited basis. Today these programs have been significantly reduced with just 76 municipal programs now active compared to the 205 earlier programs. State support has also fallen off proportionately from 21 to 7 budgeted programs. It appears that further reductions will occur during 1992 for both local and state governments.

There appear to be at least eight trends associated with noise programs that influence local and state activity. They are:

Limited Federal Activity

- Most initiatives are occurring by the U.S. Department of Transportation, the Federal Aviation Administration, and the Department of Defense, and the Office of Economic Adjustment.

Restricted Federal Focus

- The emphasis has been transportation planning related (i.e., airports and highways) along with military installations.

State and Local Responsibility

- President Reagan shifted a major portion of the federal responsibility to state and local governments, but without any federal assistance or support.

Continued Enactment

- Although the Noise Control Act was never repealed by Congress, it continues, but is essentially dormant.

Consolidated Budgeting and Reduced Enforcement

- Financial support has either been eliminated or consolidated with other programs due to budget constraints, thereby influencing significantly the enforcement process.

Privatization

- The public has turned to the private sector for assistance, and some businesses have incorporated the control of noise into their corporate strategy.

Professional Societies / Standards Groups

- Assistance in many of these areas now resides heavily with professional societies and organizations (e.g., American National Standards Institute, American Acoustical Society, Institute of Noise Control Engineers, American Society for Testing and Materials, Society of Automotive Engineers, National Association for Noise Control Offices, National Organization to Insure A Sound Control Environment, etc.)

Recognition and Litigation

- The public still considers noise to be an important environmental concern and, oftentimes their primary remedy involves litigation, which is only marginally effective.

Summary of Working Group Discussion

The purpose of Working Grouping VIII: State and Local Strategies was to develop strategies for noise abatement at the state and local levels. Measures to be considered included community noise ordinances, land-use planning, and other source-path-receiver controls. The group explored the status of state and local noise programs and recommended strategies in which federal, state, and local governments can work together for maximum efficiency, using both regulatory and nonregulatory measures.

Clearly the emphasis is not to dwell on legislative history and the inconsistency of support for environmental noise control by the federal government, which in turn has impacted state and local efforts. The key is intergovernmental cooperation and public-private partnerships that are innovative and that protect the public's concern for ensuring the amenity of quiet as a sensory right as we approach the 21st century. Essential to enhancing the comfort and enjoyment of the biosphere is the strategic planning of our environment which must consider the three-dimensional use of space, time as a 24-hour resource, and the preservation of all five human senses.

The members of the working group developed a consensus type process whereby a series of recommended goals and plan elements were prepared during the working group session. In total there were 10 goals recommended, along with 31 plan elements recommended to achieve these goals. All members of the working group reviewed and agreed upon these recommendations before they were presented to the conferees at the close of the symposium.

Recommendations

Goal 1

Develop an integrative plan of noise strategies involving all levels of government—federal, state, and local.

- Establish an organizational entity (e.g., the Office of Noise Abatement and Control (ONAC) within the EPA that is an advocate for regulatory and nonregulatory community noise management.
- Establish a Federal Interagency Committee on Noise (FICON)-type advisory board within this organizational entity of EPA.
- Utilize a telecommunication system for governmental/association/institutional interchange of noise-related information.
- Develop a multi-media system of communication and analysis for the presentation of noise-related information.
- Establish an information dissemination center (e.g., Technical Assistance Center).
- This organizational entity within EPA must be subject to a total quality management (TQM) philosophy of effectiveness.

Goal 2

Recommend a federal funding mechanism to support the activities of this ONAC type entity within EPA.

- Establish congressional legislation to authorize and appropriate funds for a cost-effective ONAC-type entity.
- Establish state/local grant criteria and mechanisms to support state and local noise programs, including demonstrations that would follow the same format as other EPA programs or other effective models found in either the public or private sector.
- Integrate economic cost-benefit factors into any noise regulations promulgated and prevention strategies implemented.

Goal 3

Propose a regulatory and nonregulatory mechanism that forges a public/private partnership for noise control.

- Establish a vehicle for promoting public/private partnerships using support type organizations, (e.g., National Council of Acoustical Consultants, National Association for Noise Control Offices, Institute of Noise Control Engineering, Acoustical Society of America, American National Standards Institute, American Society for Testing and Materials).
- Advocate and assist private sector marketing plans that incorporate the consumer amenity of quiet similar to initiatives found among the motel industry (e.g., LaQuinta, Red Roof, Embassy Suites).
- Develop a real estate transfer program that uses both regulatory and voluntary processes for conveying or disclosing noise information (e.g., real estate map, mortgage, title transfer).
- Integrate a climatic and acoustical sensory outdoor display system that can be mounted on buildings (e.g., banks). Such a system would display weather and noise information.

Goal 4

Encourage a process for innovation to provide guidance and information feedback to the users.

- Reconstitute and strengthen through a grant mechanism: "Each Community Helps Others," and Technical Assistance Center programs, including the funding of personnel.
- Implement an electronic interactive communication system (e.g., Bitnet, CompuServe, Prodigy) for noise information dissemination.

Goal 5

Review ONAC's original program for state and local assistance in terms of both positive and negative experiences.

- Prepare a document recounting ONAC customer experiences.
- Interview former ONAC administrative staff and their "customers."
- Analyze documents and policies that were produced by ONAC in terms of their effectiveness.

Goal 6

Learn from private industry experiences, both positive and negative, relating to ONAC and their own noise control initiatives.

- Prepare case study format describing private sector experience in marketing the amenity of quiet (Chambers of Commerce, Motorcycle Industry Council, American Society of Heating, Refrigeration, and Electric, Power Equipment Council, Appliance Manufacturers Council, etc.).
- Inventory advertising programs used by industry that incorporated noise control measures based on engineering control.

Goal 7

Encourage the use of spatially applied technologies, (i.e., Geographical Information Systems (GIS) and multi-media simulations) to support the other goals.

- Develop a Geographical Information System (GIS) relational data base that incorporates noise.
- Utilize two- and three-dimensional spatially applied software for multiple noise sources.
- Integrate multisensory simulation model incorporating visual, auditory, olfactory, and tactile elements.
- Utilize a strategic planning process for noise control that incorporates temporal, spatial, and sensory elements.
- Three-dimensionalize standards and criteria for noise pertaining to land use (i.e., space use) compatibility planning.

Goal 8

Develop a conflict resolution management system for noise control to supplant the litigatory process.

- Develop training materials and aids that include role playing, simulation and gaming for a variety of situations.
- Perform mediation and negotiation sessions with potentially affected parties.

Goal 9

Encourage U.S. competitiveness in the world marketplace through a "buy quiet" approach to procurement and inform industry and community of economic benefits.

- Establish noise criteria, and interact with international noise standards committees and organizations (e.g., European Economic Community, Organization for Economic Co-operation and Development, International Standards Organization (ISO), etc.).
- Encourage private sector, at state and local levels, to increase their market share in national and international arena by producing quiet products.
- Develop a system of benefits for those participating.

Goal 10

Basic Education Training

- Develop a series of model ordinances and codes.
- Train governmental and nongovernmental officials (public and private sectors) in procedures, methods, technologies bearing on noise programs and potential conflicts.
- Recommend certification standards for noise control personnel.
- Produce public outreach materials for the general public and target institutions to receive these materials in both public and private sectors.
- Emphasize interdisciplinary cross-training of personnel responsible for noise with other environmental-related fields.

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WORKING GROUP VIII MEMBERS

Clifford R. Bragdon, PhD, AICP, Chair
Special Assistant, Office of the President
Professor of City Planning
Carnegie Building
Georgia Institute of Technology
Atlanta, GA 30332-0325

Edward J. DiPolvere, MS
New Jersey Department of Environmental Protection and Energy
CN 027
401 East State Street
Trenton, NJ 08625

Trevis Markle
Assistant Director
Department of Environmental Programs
Metropolitan Washington Council of Governments
777 North Capitol Street, NE
Washington, DC 20002

Howard Schechter
Director
Midwestern Environmental Assistance Center
6561 North Seeley Avenue
Chicago, IL 60645

Noral Stewart, PhD
President
Stewart Accoustical Consultants
P.O. Box 30461
Raleigh, NC 27612

WORKING GROUP IX
REGULATORY ALTERNATIVES

Henning E. von Gierke - Chair

Introduction

The Noise Control Act (NCA) of 1972 with its amendment by the Quiet Communities Act of 1978 declared a very reasonable, timely, and laudable goal and policy of the United States: to promote an environment for all Americans free from noise that jeopardizes their health or welfare. To achieve this goal, the NCA outlines a multipronged approach assigning noise abatement and control duties to the Environmental Protection Agency (EPA) and other federal agencies concerning:

- Identification of noise levels that jeopardize public health and welfare.
- Identification of the major noise sources that are the major contributors to the noise environment.
- Establish noise emission standards for major noise sources including test procedures and provide information on control technology.
- Control and abatement of aircraft noise.
- Interstate motor carriers noise emission standards.
- Labeling requirements for some noise emitting and noise reducing products.
- Research and public education requirements, including development of low noise-emission products.
- Coordination of federal, state, and local noise abatement policies and approaches.

It is obviously a very comprehensive and long-range program where the effectiveness of the various components of the overall system have different time scales and are interdependent with respect to many aspects: the combination of regulations, education, the marketplace, and research progress are to reduce our environmental noise exposure to the desired level. Somewhat impatiently, the NCA decreed firm directives for publication of some reports and some regulatory actions; some of these tight schedules might not have been beneficial to the overall effort. The NCA established no review and oversight procedures to evaluate the effectiveness and interaction of the various program phases and to facilitate national consensus building.

The achievements of EPA's Office of Noise Abatement and Control (ONAC) in promoting and coordinating these goals during the first decade of its existence and the shortcomings with respect to follow-up activity during the second decade, are well summarized in the report to the Administrative Conference of the United States, *The Dormant Noise Control Act and Options to Abate Noise Pollution* (Shapiro, 1991). Where should we go from here? What have we, the concerned technical community, learned from the past history and what are our recommendations to revitalize the national noise abatement effort in an efficient, cost-effective way? To what extent should the baselines, the approaches, the short-term and long-term goals be updated and/or modified to contribute at the appropriate time to progress toward the overall goal? Who should be executing and who should be coordinating these efforts, realizing that during the last decade of ONAC's inactivity many capabilities and initiatives continued in other government and voluntary sector programs? (Suter & von Gierke, 1987). In addition, international programs and activities grew markedly during these last 10 years,

primarily through European Community competition. Following the United States' initial lead in environmental noise abatement, many of the European organized government activities probably surpassed ours. Now European governments try to harmonize the regulations and programs among the various countries.

These are some of the questions our Working Group IX on "Regulatory Alternatives" discussed. Three-quarters of the working group members were involved in the early phases of our national noise control efforts advising EPA, the Federal Aviation Administration (FAA), Department of Transportation (DOT), National Institutes of Health (NIH), Department of Defense (DOD), or the Occupational Safety and Health Administration (OSHA), and were collaborating on reaching consensus on fundamental technical issues such as: "What noise levels jeopardize public health and welfare?" and "What are our major noise sources and how can they best be controlled?" We have biologists, psychologists, physicists, engineers, and legal experts in the group, most of whom continued leading and contributing to voluntary sector noise abatement and standardization efforts without government support after ONAC's leadership waned.

Among the questions the group discussed are the following:

- One of the baseline technical documents for execution of the NCA is the *Levels Document* (U.S. Environmental Protection Agency, 1974; von Gierke, 1975) identifying what noise levels affect public health and welfare. Does it need updating?
- Do the guidelines for environmental impact statements with respect to noise need updating? (Committee on Hearing, Acoustics, and Bioacoustics, 1977).
- What is our noise environment? How did it and will it change? What are the major noise sources? Do we need a National Environmental Noise Assessment Program?
- Where should regulatory authority rest and where should it be applied? How effective is the technical and policy guidance of the Federal Interagency Committee on Noise (FICON)?
- How can a national, technical consensus best be established and what regulatory, technical, and product advisory committees would be desirable?
- How can the national noise abatement effort profit most effectively and without duplication from the national voluntary consensus standards system? How can federal and voluntary efforts best be harmonized?
- How can we become more effective in International Standardization with respect to noise measurement, source emission and testing, and safety to support our competitiveness and trade?

Participation in the international noise abatement efforts does not only concern public health and welfare but includes our national interests as well.

It was not possible to discuss all of these problems during the short meeting time of the group not to mention to reach detailed final consensus recommendations. However, I hope we agreed that these are all problems that must be attacked and solved if we want to be in a position to predict and control our noise environment by the year 2000.

Summary of Working Group Discussion

The working group discussed adequacy of present legislation with respect to noise abatement and potential amendments, implementation of the legislation and suggestions for its improvement, responsibilities with respect to testing, standards, and labeling of noise sources, and finally, mechanisms for establishing national consensus for regulatory alternatives. The group realized that, for exhaustive discussion of all the topics the time was much too short. Several of the items discussed would have needed representation from several government agencies and from several industrial sectors to arrive at final recommendations endorsed in detail by all members of the group. Some of the suggestions listed resulted in responses from the audience during their presentation, which would require careful consideration before detailed recommendations are worked out. Consequently, some of the suggestions listed are more long range, and need discussion by a larger group with more time available. However on all points below, consensus of the group was reached in principle.

By far the most important recommendation, which is the foundation for all other efforts and considerations proposed, concerns *refunding of the NCA of 1972*. The present situation leaves EPA with legal responsibilities it cannot carry out and

through preemption actually strangles noise control efforts in individual states.

Recommendations

Legislation

1. **Noise Control Act**
   - The present Noise Control Act provides a good basis for reactivating the implementation of a national noise abatement program. Funding should be provided for EPA's Office of Noise Abatement and Control (ONAC).
   - Any future amendments on noise from surface vehicles should include consideration of transferring certain responsibilities to DOT similar to the provisions for aircraft noise. The U.S. Department of Transportation should set and enforce noise limits for new and operating aircraft, railroads, transit vehicles, buses, and medium and heavy trucks. The FAA, FRA, and FHWA have most of the responsibility for these actions and they should be given the authority for new vehicles.
   - Any amendments that concern the health and welfare of citizens, especially research and setting criteria, should include coordination with and/or participation of the Public Health Service (NIH, NIOSH, NIDCD).
2. **National Environmental Policy Act (NEPA)**
   - The Council on Environmental Quality (CEQ) shall retain the authority to oversee federal agency implementation of the National Environmental Policy Act (NEPA), including preparation of Environmental Impact Statements (EIS).
   - The EPA shall retain the authority to review and evaluate Environmental Impact Statements with respect to the technical aspects of noise.
   - The guidelines for evaluating noise effects in EIS that were developed under the National Research Council in the 1970s should be updated to include current experience and technical progress, and should be utilized by the federal agencies in their analysis of the environmental impacts of their proposed actions. The update should include guidance to address situations in which noise disturbs people and disrupts their everyday lives.

Implementation

1. **Development of National Noise Action Plan**

   The Noise Control Act establishes the national policy and provides means and authorities for its implementation, but it does not establish an action plan with specific goals and priorities with societal benefits and costs. The development of a national noise control action plan remains the top priority for any new federal efforts in this area. The plan needs to be developed through a consultative process that would include hearings, workshops, and conferences, in which the opportunity for participation is afforded to all directly and materially affected persons, including public and private groups, industry, commerce, as well as academic and governmental agencies at the federal, state, and local levels. The plan needs to define the health and welfare problems to be solved, and for each problem area it needs to obtain consensus of specific quantitative goals, determine the existence of solutions within present or future technology, and establish priorities, resource allocation, and schedule for each goal.
2. **Agency Responsibilities**
   - EPA should be the overall coordinator for a federal noise policy. The U.S. Department of Labor should continue to have responsibility for setting and enforcing noise limits for workers' exposure to industrial equipment in plants and on construction sites (OSHA) and in mines (MSHA).
   - States should have authority to set and enforce noise limits for old cars and light trucks and for operating recreational vehicles such as off-road vehicles, snowmobiles, power boats, and motorcycles.
   - Local government should have the authority for property-line statutes regulating noise levels. Local governments should have responsibility for building codes that specify transmission losses through floors, ceilings, walls, and windows of housing units, unless these building codes are preempted by state codes. Adoption of uniform code for multifamily structures should be encouraged at all levels of government.

- All levels of government should encourage voluntary reductions in noise at the source. The approach that has been adopted by EPA's indoor air program under the SARA legislation may serve as a partial model.

3. **Review/Updating of Key Documents**
   - Of special consideration is Section 14(d) of the Noise Control Act relating to identifying trends in noise exposure and response, ambient levels, and compliance data and to determine otherwise the effectiveness of noise abatement actions through the collection of social and human response data.
   - The document *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare With an Adequate Margin of Safety*, should be reviewed and an appropriate revision or supplement prepared as required by the Noise Control Act. Prior to final release, this document should be reviewed and commented on by organizations outside the EPA.

Testing, Standards, and Labeling

1. The EPA should encourage the National Institute for Standardization and Technology (NIST) to reestablish research in the areas of noise control, the measurement of noise, and the evaluation of the effects of noise. In the past, NIST provided an important resource for research in these areas which contributed significantly to EPA requirements.
2. The EPA should provide leadership in encouraging laboratory accreditation by NIST for noise measurement standards for labeling and other regulatory purposes, and the negotiation of appropriate reciprocal data recognition agreements with foreign governments.
3. EPA and other federal agencies responsible for noise and noise control should participate actively in the development of voluntary consensus standards related to noise measurement, its biological effects and noise control. Participation in the voluntary consensus standards systems:
   - is a cost-effective way to make use of available expertise,
   - assumes coordination of all parties interested in control of noise,
   - assumes independent review and public comment on all proposed standards and,
   - would be consistent with the federal government's encouragement of the use of voluntary consensus standards.
4. Voluntary labeling program. EPA should establish a mechanism to enable voluntary disclosure of noise emission in a prescribed form of notice for products in identified product classes based on noise measurements made in accordance with one or more voluntary standards. Together, these standards should meet the criteria for measurement and test standards specified by EPA to identify the protective purposes and metrics of the noise emission data to be disclosed. This criteria should also be designed to enable the test data to be submitted to foreign regulatory authorities in accordance with GATT provisions.
5. International standards. United States participation in international standardization through the American National Standards Institute (ANSI) with respect to noise measurement, source emission and testing, noise annoyance, and safety must become more active and proactive. The United States national voluntary system needs active participation by the various governmental agencies in the standards development process which involves investment of technical manpower and funding support for travel and funding of meetings. Funding support for specific standards projects should be considered. This effort is vital to United States competitiveness in international trade. United States national standards on measurement and testing are likely to become more and more dependent on international standards.

Establishing National Consensus for Regulatory Alternatives

1. **Federal Interagency Committee on Noise (FICON).** In its planning and formulating noise-abatement policy, a newly constituted Office of Noise Abatement and Control should regularly convene a standing federal interagency committee similar to the current Federal Interagency Committee on Noise. Agencies represented on this committee should include, EPA, DOT (FAA, FHWA, FRA), DOD, HUD, VA, HHS (PHS/NIH) and CEQ. Recommendations of the federal interagency committee

should be made available to affected publics for comment, as should proposed modifications to existing federal regulations or policies based on committee's recommendations.

2. **Technical Advisory Committee.** Technical decisions by FICON, EPA, and other government agencies concerning noise, its control, and its effects on people should be based on recommendations by authoritative technical advisory committees. A cost effective and established way to accomplish this would be to use the expertise which resides at the National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine through their National Research Council (NRC). Under the present structure, the NRC's Committee on Hearing, Bio-Acoustics and Biomechanics (CHABA) would be appropriate.

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WORKING GROUP IX MEMBERS

Henning E. von Gierke, PhD - Chair
Director Emeritus, Biodynamics and
Biocommunications Division
Armstrong Aerospace
Medical Research Laboratory
Wright-Patterson AFB, OH 45433-6573

Kenneth M. Eldred
Ken Eldred Engineering
722 Annursnac Hill Road
Concord, MA 01742

Richard M. Guernsey
Principal
R.M. Guernsey & Associates
P.O. Box 1517
Morristown, NJ 07962-1517

Mones E. Hawley
Executive Vice President
Jack Faucett Associates
4550 Montgomery Avenue
Suite 300 North
Bethesda, MD 20814

Ira J. Hirsh, PhD
Distinguished University Professor of
Psychology and Audiology
Washington University
Senior Research Scientist
Central Institute for the Deaf
818 S. Euclid
St. Louis, MO 63110

Daniel L. Johnson, PhD
Director of Biophysics Operations
EG&G Special Projects
P.O. Box 9100
Albuquerque, NM 87119

Timothy S. Margulies, PhD
Acoustician and Risk Manager
908 Marine Drive
Annapolis, MD 21401

Charles Schmid, PhD
Executive Director
Acoustical Society of America
365 Ericksen Avenue, #324
Bainbridge Island, WA 98110

Lucinda Swartz
Deputy General Counsel
Council on Environmental Quality
722 Jackson Place, N.W.
Washington, DC 20503
(202) 395-5750

APPENDIX I.
CONSENSUS STATEMENT: NIH CONSENSUS DEVELOPMENT CONFERENCE ON NOISE AND HEARING LOSS

January 22-24, 1990
Volume 8, Number 1

NIH Consensus Development Conferences are convened to evaluate available scientific information and resolve safety and efficacy issues related to a biomedical technology. The resultant NIH Consensus Statements are intended to advance understanding of the technology or issue in question and to be useful to health professionals and the public.

NIH Consensus Statements are prepared by a nonadvocate, non-federal panel of experts, based on: (1) presentations by investigators working in areas relevant to the consensus question during a 1-1/2 day public session; (2) questions and statements from conference attendees during open discussion periods that are part of the public session; and (3) closed deliberations by the Panel during the remainder of the second day and morning of the third. This statement is an independent report of the panel and is not a policy statement of the NIH or the Federal Government.

Copies of this statement and bibliographies prepared by the National Library of Medicine are available from the Office of Medical Applications of Research, National Institutes of Health, Building 1, Room 260, Bethesda, MD 20892.

For making bibliographic reference to the consensus statement from this conference, it is suggested that the following format be used, with or without source abbreviations, but without authorship attribution: Noise and Hearing Loss NIH Consens Dev Conf Consens Statement 1990 Jan 22-24; 8(1).

ABSTRACT

The National Institutes of Health Consensus Development Conference on Noise and Hearing Loss brought together biomedical and behavioral scientists, health care providers, and the public to address the characteristics of noise-induced hearing loss, acoustic parameters of hazardous noise exposure, individual and age-specific susceptibility and prevention strategies. Following a day and a half of presentations by experts and discussion by the audience, a consensus panel weighed the evidence and prepared a consensus statement.

Among their findings, the panel concluded that sounds of sufficient intensity and duration will damage the ear and result in temporary or permanent hearing loss at any age. Sound levels of less than 75 dB(A) are unlikely to cause permanent hearing loss, while sound levels above 85 dB(A) with exposures of 8 hours per day will produce permanent hearing loss after many years. Current scientific knowledge is inadequate to predict that any particular individual will be safe when exposed to a hazardous noise. Strategies to prevent damage from sound exposure should include the use of individual hearing protection devices, education programs beginning with school-age children,

consumer guidance, increased product noise labeling, and hearing conservation programs for occupational settings.

The full text of the consensus panel's statement follows.

INTRODUCTION

Hearing loss afflicts approximately 28 million people in the United States. Approximately 10 million of these impairments are at least partially attributable to damage from exposure to loud sounds. Sounds that are sufficiently loud to damage sensitive inner ear structures can produce hearing loss that is not reversible by any presently available medical or surgical treatment. Hearing impairment associated with noise exposure can occur at any age, including early infancy, and is often characterized by difficulty in understanding speech and the potentially troublesome symptom, tinnitus (i.e., ringing in the ears). Very loud sounds of short duration, such as an explosion or gunfire, can produce immediate, severe, and permanent loss of hearing. Longer exposure to less intense but still hazardous sounds, commonly encountered in the workplace or in certain leisure time activities, exacts a gradual toll on hearing sensitivity, initially without the victims' awareness. More than 20 million Americans are exposed on a regular basis to hazardous noise levels that could result in hearing loss. Occupational exposure, the most common cause of noise-induced hearing loss (NIHL) threatens the hearing of firefighters, police officers, military personnel, construction and factory workers, musicians, farmers, and truck drivers, to name a few. Live or recorded high-volume music, recreational vehicles, airplanes, lawn-care equipment, woodworking tools, some household appliances, and chain saws are examples of non-occupational sources of potentially hazardous noise. One important feature of NIHL is that it is preventable in all but certain cases of accidental exposure. Legislation and regulations have been enacted that spell out guidelines for protecting workers from hazardous noise levels in the workplace and consumers from hazardous noise during leisure time pursuits. Inconsistent compliance and spotty enforcement of existing governmental regulations have been the underlying cause for their relative ineffectiveness in achieving prevention of NIHL. A particularly unfortunate occurrence was the elimination of the Office of Noise Abatement and Control within the Environmental Protection Agency in 1982.

On January 22-24, 1990, the National Institute on Deafness and Other Communication Disorders, together with the Office of Medical Applications of Research of the National Institutes of Health convened a Consensus Development Conference on Noise and Hearing Loss. Cosponsors of the conference were the National Institute of Child Health and Human Development, the National Institute on Aging, and the National Institute for Occupational Safety and Health of the Centers for Disease Control. The effects of environmental sounds on human listeners may include:

- Interference with speech communication and other auditory signals.
- Annoyance and aversion.
- Noise-induced hearing loss.
- Changes in various body systems.
- Interference with sleep.

This conference was entirely centered on NIHL. The panel focused on five questions related to noise and hearing loss:

- What is noise-induced hearing loss?
- What sounds can damage hearing?
- What factors, including age, determine an individual's susceptibility to noise-induced hearing loss?
- What can be done to prevent noise-induced hearing loss?
- What are the directions for future research?

Following a day and a half of presentations by experts in the relevant fields and discussion from the audience, a consensus panel comprising specialists and generalists from the medical and other related scientific disciplines, together with public representatives, considered the evidence and formulated a consensus statement in response to the five previously stated questions.

WHAT IS NOISE-INDUCED HEARING LOSS?

Sounds of sufficient intensity and duration will damage the ear and result in temporary or permanent hearing loss. The hearing loss may range from mild to profound and may also result in tinnitus. The effect of repeated sound overstimulation is cumulative over a lifetime and is not currently treatable. Hearing impairment has a major impact on one's communication ability and even

mild impairment may adversely affect the quality of life. Unfortunately, although NIHL is preventable, our increasingly noisy environment places more and more people at risk.

Studies of NIHL

Most studies of the association between sound exposure and hearing loss in humans are retrospective measurements of the hearing sensitivities of numerous individuals correlated with their noise exposures. The variability within these studies is usually large; thus, it is difficult to predict the precise magnitude of hearing loss that will result from a specific sound exposure. Prospective studies of selected workers' hearing levels over a long time while their sound exposures are carefully monitored are costly and time-consuming and, due to attrition, require a large number of subjects. When significant hearing loss is found, for ethical reasons, exposures must be reduced, interfering with the relationships under study. Although studies of NIHL in humans are difficult, they provide valuable information not available from animal studies and should be continued.

In prospective animal studies, sound exposures can be carefully controlled, and the anatomic and physiologic correlates of NIHL can be precisely defined. Although there may be interspecies differences with respect to the absolute sound exposure that will injure the ear, the basic mechanisms that lead to damage appear to be similar in all mammalian ears.

Anatomic and Physiologic Correlates of NIHL

Two types of injury are recognized: acoustic trauma and NIHL. Short-duration sound of sufficient intensity (e.g., a gunshot or explosion) may result in an immediate, severe, and permanent hearing loss, which is termed *acoustic trauma*. Virtually all of the structures of the ear can be damaged, in particular the organ of Corti, the delicate sensory structure of the auditory portion of the inner ear (cochlea), which may be torn apart.

Moderate exposure may initially cause temporary hearing loss, termed *temporary threshold shift* (TTS). Structural changes associated with TTS have not been fully established but may include subtle intracellular changes in the sensory cells (hair cells) and swelling of the auditory nerve endings. Other potentially reversible effects include vascular changes, metabolic exhaustion, and chemical changes within the hair cells. There is also evidence of a regional decrease in the stiffness of the stereocilia (the hair bundles at the top of the hair cells), which may recover. This decrease in stereocilia stiffness may lead to a decrease in the coupling of sound energy to the hair cells, which thereby alters hearing sensitivity.

Repeated exposure to sounds that cause TTS may gradually cause permanent NIHL in experimental animals. In this type of injury, cochlear blood flow may be impaired, and a few scattered hair cells are damaged with each exposure. With continued exposure, the number of damaged hair cells increases. Although most structures in the inner ear can be harmed by excessive sound exposure, the sensory cells are the most vulnerable. Damage to the stereocilia is often the first change, specifically, alteration of the rootlet structures that normally anchor the stereocilia into the top of the hair cell. Once destroyed, the sensory cells are not replaced. During the recovery period between some sound exposures, damaged regions of the organ of Corti heal by scar formation. This process is very important because it reestablishes the barrier between the two fluids of the inner ear (perilymph and endolymph). If this barrier is not reestablished, degeneration of hair cells may continue. Further, once a sufficient number of hair cells are lost, the nerve fibers to that region also degenerate. With degeneration of the cochlear nerve fibers, there is corresponding degeneration within the central nervous system. The extent to which these neural changes contribute to NIHL is not clear.

With moderate periods of exposure to potentially hazardous high frequency sound, the damage is usually confined to a restricted area in the high-frequency region of the cochlea. With a comparable exposure to low-frequency noise, hair cell damage is not confined to the low-frequency region but may also affect the high-frequency regions. The predominance of damage in different cochlear regions with different frequency exposures reflects factors such as the resonance of the ear canal, the middle ear transfer characteristics, and the mechanical characteristics of the organ of Corti and basilar membrane.

Assessment of NIHL

Hearing loss is measured by determining auditory thresholds (sensitivity) at various frequencies (pure-tone audiometry). Complete assessment should also include measures of speech understanding and middle-ear status (immittance audi-

ometry). Pure-tone audiometry is also used in industrial hearing conservation programs to determine whether adequate protection against hazardous sound levels is provided.

The first audiometric sign of NIHL resulting from broadband noise is usually a loss of sensitivity in the higher frequencies from 3,000 through 6,000 Hertz (Hz) (i.e., cycles per second), resulting in a characteristic audiometric "notch." With additional hearing loss from noise or aging, the threshold at 8,000 Hz may worsen and eliminate this characteristic audiometric pattern. Thus, the presence or absence of NIHL cannot be established on the basis of audiometric shape, per se. The hearing loss is usually bilateral, but some degree of asymmetry is not unusual, especially with lateralized noise sources such as rifles. After moderate sound exposure, TTS may occur, and during a period of relative quiet, thresholds will return to normal levels. If the exposure continues on a regular basis, permanent threshold shifts (PTS) will result, increasing in magnitude and extending to lower and higher frequencies. If the exposures continue, NIHL increases, more rapidly in the early years. After many years of exposure, NIHL levels off in the high frequencies, but continues to worsen in the low frequencies. Although TTS and PTS are correlated, the relation is not strong enough to use TTS to predict the magnitude of permanent hearing loss.

An important consequence of the sensitivity loss associated with NIHL is difficulty in understanding speech. Whereas a large proportion of the energy in speech is contained within the low frequency range, much of the information required to differentiate one speech sound from another is contained within the higher frequencies. With significant hearing loss in the high frequencies, important speech information is often inaudible or unusable. Other interfering sounds such as background noise, competing voices, or room reverberation may reduce even further the hearing-impaired listener's receptive communication ability. The presence of tinnitus may be an additional debilitating condition.

NIHL may interfere with daily life, especially those social activities that occur in noisy settings. Increased effort is required for understanding speech in these situations, which leads to fatigue, anxiety, and stress. Decreased participation in these activities often results, affecting not only hearing-impaired individuals but also friends and family members. Hearing loss is associated with depression in the elderly and may be related to dementia and cognitive dysfunction. Systematic study of the effects of hearing loss on the quality of life have only lately focused specifically on individuals with NIHL; therefore, continued studies of this kind are desirable.

The impairment in hearing ability resulting from NIHL may vary from mild to severe. An individual's ability to communicate and function in daily life varies with the degree of loss and the individual's communication needs although these relationships are complex. The magnitude of the effect of communication ability may be estimated by a variety of scales, which are often used in disability determinations. These scales, which vary substantially in the frequencies used, the upper and lower limits of impairment, age correction, and adjustment for asymmetric hearing loss, attempt to predict the degree of communication impairment (understanding of speech) on the basis of pure-tone thresholds. There is no consensus about the validity or utility of the scales, which scale should be used, whether measures of speech understanding should be included, or whether self-assessment ratings should be incorporated into either impairment rating scales or disability determinations.

WHAT SOUNDS CAN DAMAGE HEARING?

Some sounds are so weak physically that they are not heard. Some sounds are audible but do not have any temporary or permanent after-effects. Some sounds are strong enough to produce a temporary hearing loss from which there may appear to be complete recovery. Damaging sounds are those that are sufficiently strong, sufficiently long-lasting, and involve appropriate frequencies so that permanent hearing loss will ensue.

Most of the sounds in the environment that produce such permanent effects occur over a very long time (for example, about 8 hours per workday over a period of 10 or more years). On the other hand, there are some particularly abrupt or explosive sounds that can cause damage even with a single exposure.

The line between these categories of sounds cannot be stated simply because not all persons respond to sound in the same manner. Thus, if a sound of given frequency bandwidth, level, and duration is considered hazardous, one must specify for what proportion of the population it will be hazardous and, within that proportion, by what criterion of damage (whether anatomical, audiometric, speech understanding) it is hazardous.

The most widely used measure of a sound's strength or amplitude is called "sound level," measured by a sound-level meter in units called "decibels" (dB). For example, the sound level of speech at typical conversational distances is between 65 and 70 dB. There are weaker sounds, still audible, and of course much stronger sounds. Those above 85 dB are potentially hazardous.

Sounds must also be specified in terms of frequency or bandwidth, roughly like the span of keys on a piano. The range of audible frequencies extends from about 20 Hz, below the lowest notes on a piano, to at least 16,000 or 20,000 Hz, well above the highest notes on a piccolo. Most environmental noises include a wide band of frequencies and, by convention, are measured through the "A" filter in the sound-level meter and thus are designated in dB(A) units. It is not clear what effect, if any, sound outside the frequency range covered in dB(A) measurements may have on hearing. At this time, it is not known whether ultrasonic vibration will damage hearing.

To define what sounds can damage hearing, sound level, whether across all frequency bands or taken band by band, is not enough. The duration of exposure—typical for a day and accumulated over many years—is critical. Sound levels associated with particular sources such as snowmobiles, rock music, and chain saws, are often cited, but predicting the likelihood of NIHL from such sources also requires knowledge of typical durations and the number of exposures.

There appears to be reasonable agreement that sound levels below 75 dB(A) will not engender a permanent hearing loss, even at 4,000 Hz. At higher levels, the amount of hearing loss is directly related to sound level for comparable durations.

According to some existing rules and regulations, a noise level of 85 dB(A) for an 8-hour daily exposure is potentially damaging. If total sound energy were the important predictor, an equivalent exposure could be as high as 88 dB(A) if restricted to 4 hours. (A 3-dB increase is equivalent to doubling the sound intensity.) This relation, enshrined in some standards and regulations, is a theory based on a dose or exposure defined by total energy.

In spite of the physical simplicity of a total-energy concept, other principles have been invoked to define equivalent exposures of different sound levels and durations. Early research suggested that NIHL after 10 years could be predicted from temporary threshold shifts (TTS) measured 2 minutes after a comparable single-day exposure. Those results, however, were taken to indicate that a halving of duration could be offset by a 5-dB change in sound level rather than a 3-dB change. This 5-dB rule is implemented in the Walsh-Healey Act of 1969 and subsequent Occupational Safety and Health Administration regulations for the purpose of requiring preventive efforts for noise-exposed workers. The 3-dB trading rule is agreed to in International Standards Organization (ISO) Standard 1999.2 (1989) for the purpose of predicting the amount of noise-induced hearing loss resulting from different exposures. There is no consensus concerning a single rule to be used for all purposes in the United States.

Generally, for sound levels below about 140 dB, different temporal forms of sound, whether impulse (gunshot), impact (drop forge) or steady state (turbine), when specified with respect to their level and duration, produce the same hearing loss. This does not appear to follow at levels above 140 dB, where impulse noise creates more damage than would be predicted. This may imply that impulse noise above a certain critical level results in acoustic trauma from which the ear cannot recover.

Although sound exposures that are potentially hazardous to hearing are usually defined in terms of sound level frequency bandwidths, and duration, there are several simple approximations that indicate that a sound exposure may be suspected as hazardous. These include the following: if the sound is appreciably louder than conversational level, it is potentially harmful, provided that the sound is present for a sufficient period of time. Hazardous noise may also be suspected if the listener experiences: (a) difficulty in communication while in the sound, (b) ringing in the ear (tinnitus) after exposure to the sound, and/or (c) the experience that sounds seem muffled after leaving the sound-exposure area.

In the consideration of sounds that can damage hearing, one point is clear; it is the acoustic energy of the sound reaching the ear, not its source, which is important. That is, it does not matter if the hazardous sound is generated by a machine in the workplace, by an amplifier/loudspeaker at a rock concert, or by a snowmobile ridden by the listener. Significant amounts of acoustic energy reaching the ear will create damage—at work, at school, at home, or during leisure activities. Although there has been a tendency to concentrate on the more significant occupational and transportation noise, the same rules apply to all potential noise hazards.

WHAT FACTORS, INCLUDING AGE, DETERMINE AN INDIVIDUAL'S SUSCEPTIBILITY TO NOISE-INDUCED HEARING LOSS?

One thoroughly established characteristic of NIHL is that on the average, more intense and longer-duration noise exposures cause more severe hearing loss. A second is that there is a remarkable broad range of individual differences in sensitivity to any given noise exposure. Several factors have been proposed to explain differences in NIHL among individuals; others may be associated with differences over time within the same individual. It is important to distinguish those factors whose roles in determining susceptibility are supported by a consistent body of theory and empirical evidence from other factors whose roles have been proposed but for which theory, data, or both are less conclusive.

Differences Among Individuals

Both temporary threshold shift (TTS) and permanent threshold shift (PTS) in response to a given intense noise may differ as much as 30 dB to 50 dB among individuals. Both animal research and retrospective studies of humans exposed to industrial noise have demonstrated this remarkable variation in susceptibility. The biological bases for these differences are unknown. A number of extrinsic factors (e.g., characteristics of the ear canal and middle ear, drugs, and prior exposure to noise) may influence an individual's susceptibility to NIHL. However, animal studies that have controlled these variables suggest that individual differences in inner ear anatomy and physiology also may be significant. Additional research is necessary to determine whether vascular, neural feedback (efferent system), or other mechanisms can account for and predict such individual variation.

One factor that may be associated with decreased susceptibility to NIHL is conductive hearing loss; the cochlear structures may be protected by any form of acoustic attenuation. For similar reasons, middle ear muscles, which normally serve a protective function by contracting in response to intense sound, when inoperative, can result in increased susceptibility. Among the other factors that are theoretically associated with differences in susceptibility are (a) unusually efficient acoustic transfer through the external and middle ear, as a determinant of the amount of energy coupled to the inner ear structures, and (b) preexisting hearing loss, which could imply that less additional loss would occur if the sensitive structures have already been damaged. Support for these hypotheses has been modest, in the case of the transfer function, because little empirical work has been done to test that hypothesis and, in the case of reduced sensitivity, because several studies disagree. In general, when there is a difference in average loss to a given noise exposure, those ears with previous PTS or TTS have shown somewhat less additional loss than those not previously exposed.

Findings have sometimes implicated degree of pigmentation, both of the receptor structures (melanization) and of the eye and skin, as related to susceptibility. However, these results, too, are equivocal.

Gender. There is little difference in hearing thresholds between young male and female children. Between ages 10 and 20, males begin to show reduced high-frequency auditory sensitivity relative to females. Women continue to demonstrate better hearing than men into advanced age. These gender differences are probably due to greater exposure of males to noise rather than to their inherent susceptibility to its effects.

Differences Within Individuals

Ototoxic drugs. Among the causes of differences of susceptibility to noise exposure within individuals are ototoxic drugs and other chemicals. In animal research, certain antibiotics (aminoglycocides) appear to exacerbate the damaging effects of noise exposure. Clinical evidence of corresponding effects in human patients has not been established, but precautions should be taken with regard to noise exposures of individual patients treated with these medications. Although high doses of aspirin are widely known to cause TTS and tinnitus, aspirin has not been shown to increase susceptibility to NIHL.

Age. In certain animal models there is evidence of heightened susceptibility to noise exposure shortly after birth—a "critical period" (possibly following the time when fluids fill the middle ear but before complete development of the cochlear structures). However, it is not clear that data from such animal models can be generalized to full-term normal human infants. Premature infants in noisy environments (e.g., neonatal intensive care units), however, may be at risk.

At the other extreme, increasing age has been hypothesized to be associated with increasing

susceptibility. This contention is based on the existence of presbycusis, hearing loss that increases with age and that is not known to be attributable to excessive noise exposure or other known etiology. The typical levels of presbycusis at various ages have recently been incorporated as Annex A in International Standards Organization Standard 1999.2 (1989). That standard may be used to estimate the portion of overall hearing loss that is attributable to exposure to excessive noise.

In summary, scientific knowledge is currently inadequate to predict that any individual will be safe in noise that exceeds established damage-risk criteria, nor that specific individuals will show greater-than-average loss following a given exposure. Among the many proposed explanations, the hypothesis that the resonant and transmission properties of the external and middle ear affect individual susceptibility deserves further attention. Empirical support for this hypothesis should not be difficult to obtain, but very few data have been collected on this question, both for TTS (experimentally) and PTS (retrospectively). Differences in susceptibility of the cochlear structures to NIHL may exist, but no practical approach to predicting them is yet available. Identification of susceptible humans will almost certainly be delayed until a successful animal model is available.

WHAT CAN BE DONE TO PREVENT NOISE-INDUCED HEARING LOSS?

Noise-induced hearing loss occurs every day in both occupational and nonoccupational settings. The crucial questions for prevention are as follows: (1) What can individuals do to protect themselves from NIHL? (2) What role should others such as educators, employers, or the Government play in preventing NIHL? (3) What general strategies should be employed to prevent NIHL? Answers to these questions have long been know, but solutions have not been effectively implemented in many cases. As a result, many people have needlessly suffered hearing loss.

Individual Protection Strategies

Hearing conservation must begin by providing each individual with basic information. NIHL is insidious, permanent, and irreparable, causing communication interference that can substantially affect the quality of life. Ringing in the ears and muffling of sounds after sound exposure are indicators of potential hazard. Dangerous sound exposures can cause significant damage without pain, and hearing aids do not restore normal hearing. Individuals should become aware of loud noise situations and avoid them if possible or properly use hearing protection. It is important to recognize that both the level of the noise and its duration (i.e., exposure) contribute the overall risk. Certain noises, such as explosions, may cause immediate permanent damage.

Many sources, such as guns, power tools, chain saws, small airplanes, farm vehicles, firecrackers, some types of toys, and some medical and dental instruments may produce dangerous exposures. Music concerts, car and motorcycle races, and other spectator events often produce sound levels that warrant hearing protection. Similarly, some stereo headphones and loudspeakers are capable of producing hazardous exposure. Parents should exercise special care in supervising the use of personal headset listening devices, and adults and children alike should learn to operate them at safe volume settings.

Non-occupational Strategies

Hearing loss from nonoccupational noise is common, but public awareness of the hazard is low. Educational programs should be targeted toward children, parents, hobby groups, public role models, and professionals in influential positions such as teachers, physicians, audiologists and other healthcare professionals, engineers, architects, and legislators. In particular, primary healthcare physicians and educators who deal with young people should be targeted through their professional organizations. Consumers need guidance and product noise labeling to assist them in purchasing quieter devices and in implementing exposure reduction strategies. The public should be made aware of the availability of affordable, effective hearing protectors (ear plugs, ear muffs, and canal caps). Hearing protection manufacturers should supply comprehensive instructions concerning proper protector use and also be encouraged to increase device availability to the public sector. Newborn nurseries, including neonatal intensive care units, should be made quieter. Medical and dental personnel should be trained to educate their patients about NIHL.

Individuals with significant noise exposure need counseling. Basic audiometric evaluations should be widely available. The goal is to detect early noise-induced damage and interrupt its progression *before* hearing thresholds exceed the normal range.

Occupational Strategies

Hearing conservation programs for occupational settings must include the following interactive components: sound surveys to assess the degree of hazardous noise exposure, engineering and administrative noise controls to reduce exposures, education to inform at-risk individuals why and how to prevent hearing loss, hearing protection devices (earplugs, earmuffs, and canal caps) to reduce the sound reaching the ear, and audiometric evaluations to detect hearing changes. Governmental regulations that currently apply to most noisy industries should be revised to encompass all industries and all employees, strengthened in certain requirements, and strictly enforced with more inspections and more severe penalties for violations.

Many existing hearing conservation programs remain ineffective due to poor organization and inadequately trained program staff. Senior management must use available noise controls, purchase quieter equipment, and incorporate noise reduction in planning new facilities. Noise exposures must be measured accurately and the degree of hazard communicated to employees. Hearing protection devices must be available that are comfortable, practical for the demands of work tasks, and provide adequate attenuation. Labeled ratings of hearing protector attenuation must be more realistic so that the degree of protection achieved in the workplace can be properly estimated. Each employee must be individually fitted with protectors and trained in their correct use and care. Employees need feedback about their audiometric monitoring results annually.

Employers need to monitor program effectiveness by using appropriate techniques for analysis of group audiometric data. By detecting problem areas, managers can prioritize resource allocations and modify company policies to achieve effectiveness. Potential benefits include reduced costs for worker's compensation, enhanced worker morale, reduced absenteeism, fewer accidents, and greater productivity. Enactment of uniform regulations for awarding worker's compensation for occupational hearing loss would stimulate employers' interest in achieving effective hearing conservation programs. Equitable criteria for compensability should be developed based on scientific investigations of the difficulties in communication and other aspects of auditory function encountered in everyday life by persons with differing degrees of NIHL.

General Strategies

Both nonoccupational and occupational NIHL could be reduced by implementing broader preventive efforts. Labeling of consumer product noise emission levels should be enforced according to existing regulations. Incentives for manufacturers to design quieter industrial equipment and consumer goods are needed along with regulations governing the maximum emission levels of certain consumer products, such as power tools. Reestablishment of a Federal agency coordinating committee with central responsibility for practical solutions to noise issues is essential. Model community ordinances could promote local planning to control environmental noise and, where feasible, noise levels at certain spectator events. High visibility media campaigns are needed to develop public awareness of the effects of noise on hearing and the means for self-protection. Prevention of NIHL should be part of the health curricula in elementary through high schools. Self-education materials for adults should be readily available.

WHAT ARE THE DIRECTIONS FOR FUTURE RESEARCH?

The panel recommends that research be undertaken in two broad categories: (1) Studies that use existing knowledge to prevent NIHL in the immediate future, and; (2) research on basic mechanisms to prevent NIHL in the long-term future.

- Development of rationale and collection of empirical data to evaluate systems for combining sound level and duration to predict NIHL.
- Longitudinal studies to further delineate responses of the ear to noise over time in different groups of people with varying levels of exposure.
- Continued investigation of engineering noise measurement and control techniques, such as acoustic intensity measurement, active noise-cancellation systems, and cost-benefit analyses of noise reduction.
- Development and investigation of hearing protector designs that provide improved wearer comfort, usability, and more natural audition.
- Development of repeatable laboratory procedures that incorporate behavioral tests to yield realistic estimates of hearing protector attenuation performance that are accepted for device labeling purposes.

- Empirical evaluation of the efficacy of hearing conservation programs and the field performance of hearing protection devices in industry.
- Development and validation of evaluation techniques for detection of the following: (a) subtle changes in hearing resulting from noise exposure and (b) early indicators of NIHL.
- Determination of the pathophysiological correlates of TTS and PTS.
- Investigation of the anatomic and physiologic bases of presbycusis and interactive effects with NIHL.
- Investigation of genetic bases for susceptibility to NIHL, using contemporary techniques, including molecular biology.
- Further studies of drugs (e.g., vasodilating agents) and other pre-exposure conditions (e.g., activation of efferent systems or exposure to "conditioning" noise) that have been suggested in preliminary reports to protect the inner ear from NIHL and elucidation of the underlying mechanisms.
- Investigation into the physiologic mechanisms underlying the synergistic effects of certain drugs and noise exposure in animal models.

CONCLUSIONS AND RECOMMENDATIONS

- Sounds of sufficient intensity and duration will damage the ear and result in temporary or permanent loss at any age.
- NIHL is characterized by specific anatomic and physiologic changes in the inner ear.
- Sounds with levels less than 75 dB(A), even after long exposures, are unlikely to cause permanent hearing loss.
- Sounds with levels above 85 dB(A) with exposures of 8 hours per day will produce permanent hearing loss after many years.
- There is a broad range of individual differences among people in the amount of hearing loss each suffers as a result of identical exposures.
- Current scientific knowledge is inadequate to predict that any particular individual will be safe when exposed to a hazardous noise.
- Because sources of potentially hazardous sound are present in both occupational and nonoccupational settings, personal hearing protection should be used when hazardous exposures are unavoidable.
- Vigorous enforcement of existing regulations, particularly for the workplace and consumer product labeling would significantly reduce the risk of workplace NIHL. Regulations should be broadened to encompass all employees with hazardous noise exposures.
- Application of existing technologies for source noise control, especially in the manufacture of new equipment and construction of new facilities, would significantly reduce sound levels at the ear.
- In addition to existing hearing conservation programs, a comprehensive program of education regarding the causes and prevention of NIHL should be developed and disseminated, with specific attention directed toward educating school-age children.

NIDCD CONSENSUS DEVELOPMENT PANEL

Patrick E. Brookhouser, MD
Conference and Panel Chairperson
Director
Boys Town National Research Hospital
Professor and Chair
Department of Otolaryngology
Creighton University
Omaha, Nebraska

John Gordon Casali, PhD
Director
Auditory Systems Laboratory
Department of Industrial Engineering
and Operations Research
Virginia Polytechnic Institute and
State University
Blacksburg, Virginia

Francis I. Catlin, MD, ScD
Professor
Department of Otolaryngology
and Communicative Sciences
Baylor College of Medicine
Houston, Texas

Marilyn E. Demorest, PhD
Professor
Department of Psychology
University of Maryland Baltimore County
Catonsville, Maryland

Judy R. Dubno, PhD
Associate Professor of Surgery
Division of Head and Neck Surgery
University of California at
Los Angeles School of Medicine
Los Angeles, California

George A. Gates, MD
Professor and Vice Chairman
Department of Otolaryngology
Washington University
St. Louis, Missouri

Ira J. Hirsh, PhD
Professor
Department of Psychology
Washington University
Director of Research Emeritus
Central Institute for the Deaf
St. Louis, Missouri

Patricia A. Leake, PhD
Associate Professor in Resident
Department of Otolaryngology
Coleman-Epstein Laboratories
University of California
San Francisco, California

Kevin John Murphy, MD, FAAP
Assistant Professor of Clinical Pediatrics
Washington University Medical School/
Northwest Pediatrics
Florissant, Missouri

Julia Doswell Royster, PhD
President
Environmental Noise Consultants, Inc.
Cary, North Carolina

Evelyn O. Talbott, DrPH
Assistant Professor of Epidemiology
Department of Epidemiology
University of Pittsburgh
Graduate School of Public Health
Pittsburgh, Pennsylvania

Bonnie Tucker, JD
Attorney/Professor of Law
Arizona State University College of Law
Tempe, Arizona

Charles S. Watson, PhD
Professor and Chair
Department of Speech and Hearing Sciences
Speech and Hearing Center
Indiana University
Bloomington, Indiana

Laura Ann Wilber, PhD
Professor
Department of Audiology and
Hearing Impairment
Northwestern University
Evanston, Illinois

NIDCD SPEAKERS

Peter W. Alberti, PhD, MB
"Clinical Criteria: Noise or Not?"

Alf Axelsson, MD, PhD
"Noise Exposure in Adolescents and Young Adults"

Elliott H. Berger, MS
"Hearing Protection—the State of the Art (Circa 1990) and Research Priorities for the Coming Decade"

Barbara A. Bohne, PhD
"Patterns of Cellular Degeneration in the Inner Ear Following Excessive Exposure to Noise"

William W. Clark, PhD
"Noise Exposure and Hearing Loss from Leisure Activities"

Robert A. Dobie, MD
"Effects of Noise-Induced Hearing Loss on Quality of Life"

Mary Florentine, PhD
"Prevention Strategies: Education"

Kenneth J. Gerhardt, PhD
"Prenatal and Perinatal Risks"

Donald Henderson, PhD
"Acoustic Parameters of Hazardous Noise Exposures"

Larry E. Humes, PhD
"Individual Susceptibility—Nonauditory Factors"

M. Charles Liberman, PhD
"Biological Bases of Acoustic Injury"

John H. Mills, PhD
"Noise and the Aging Process"

Anna K. Nabelek, PhD
"Interactions Between Hearing Loss and the Environment"

William Noble, PhD
"Evaluation of Disability and Handicap"

Gerald R. Popelka, PhD
"The Effects of Certain Auditory Factors on Individual Susceptibility to Noise"

Brenda Ryals, PhD
"Critical Periods and Acoustic Trauma"

Richard Salvi, PhD
"Interaction Between Noise and Other Agents"

Edgar A.G. Shaw, PhD
"The Measurement of Noise Exposure and the Assessment of Risk"

Noral D. Stewart, PhD
"Noise Reduction to Prevent Hearing Damage—State of the Art, Implementation Problems, and Future Directions"

Henning E. von Gierke, DrEng
"The Noise-Induced Hearing Loss Problem"

W. Dixon Ward, PhD
"Impulse/Impact Vs. Continuous Noise"

NIDCD PLANNING COMMITTEE

Ralph F. Naunton, MD
Planning Committee Chairperson
Director
Extramural Program
Division of Communication Sciences and Disorders
National Institute on Deafness and Other Communication Disorders
National Institutes of Health
Bethesda, Maryland

Patrick E. Brookhouser, MD
Director
Boys Town National Research Hospital
Professor and Chair
Department of Otolaryngology
Creighton University
Omaha, Nebraska

William W. Clark, PhD
Director
Graduate Program in Communication Sciences
Central Institute for the Deaf
St. Louis, Missouri

Jerry M. Elliott
Program Analyst
Office of Medical Applications of Research
National Institutes of Health
Bethesda, Maryland

John H. Ferguson, MD
Director
Office of Medical Applications of Research
National Institutes of Health
Bethesda, Maryland

William H. Hall
Director of Communications
Office of Medical Applications of Research
National Institutes of Health
Bethesda, Maryland

Donald Henderson, PhD
Professor and Chairman
Communicative Disorders and Sciences
State University of New York at Buffalo
Buffalo, New York

Karen Jackson
Information Coordinator
National Institute on Deafness and Other Communication Disorders
National Institutes of Health
Bethesda, Maryland

James F. Kavanagh, PhD
Associate Director
Center for Research for Mothers and Children
National Institute of Child Health and Human Development
National Institutes of Health
Bethesda, Maryland

William Melnick, PhD
Professor
Department of Otolaryngology
University Hospital Clinics
Ohio State University
Columbus, Ohio

Andrew Monjan, PhD, MPH
Chief
Neurobiology and Neuropsychology Unit
Neuroscience and Neuropsychology of Aging Program
National Institute on Aging
National Institutes of Health
Bethesda, Maryland

Lt. Col. Michael J. Moul, PhD
Assistant Director
Army Audiology and Speech Center
Walter Reed Army Medical Center
Washington, D.C.

J. Buckminster Ranney, PhD
Deputy Director
Division of Communication Sciences and Disorders
National Institute on Deafness and Other Communication Disorders
National Institutes of Health
Bethesda, Maryland

Dina Rice
Conference Coordinator
Prospect Associates
Rockville, Maryland

Alice H. Suter, PhD
Visiting Scientist
National Institute on Occupational Safety and Health
Centers for Disease Control
Cincinnati, Ohio

Susan Wallace, MFA
Conference Coordinator
Prospect Associates
Rockville, Maryland