



P R O C E E D I N G S :



Best Practices in Hearing Loss Prevention

October 28, 1999 • Detroit, Michigan



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



Proceedings: **Best Practices in** **Hearing Loss Prevention**

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**Occupational and Environmental
Health Sciences Department, Wayne State University**

October 28, 1999

Detroit, Michigan

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Best Practices in Hearing Loss Prevention

October 28, 1999

Introduction

Approximately 30 million workers are exposed to hazardous noise on the job. In Michigan, an estimated 86,000 workers have work-related noise-induced hearing loss. Despite the fact that it is 100 percent preventable, loss of hearing is one of the most prevalent occupational diseases in the United States and the second highest self-reported workplace injury or illness.

On October 28, 1999, leaders from industry, government, labor, professional and trade organizations, and academia met in Detroit to share best practices for preventing work-related hearing impairment. The symposium highlighted an array of proven strategies and new advancements for protecting workers' hearing.

The symposium was sponsored by the National Institute for Occupational Safety and Health (NIOSH), the National Hearing Conservation Association (NHCA), and the Occupational and Environmental Health Sciences Department of Wayne State University. Additional support for this program was provided by the Michigan Occupational Safety and Health Administration, the Michigan Industrial Hygiene Society, the American Industrial Hygiene Association, the National Safety Council, the Institute of Noise Control Engineering, and the Douglas A. Fraser Center for Workplace Issues.

Topics discussed included noise abatement and control, advancements in hearing protector design, practical solutions for successful hearing protection programs, and new federal and state initiatives. The conference provided an opportunity for the exchange of ideas on workplace hearing-loss prevention and to interact with colleagues responsible for instituting successful programs in their organizations.

NIOSH would like to thank Lee Hager, president of the National Hearing Conservation Association and Pat Brogran, Ph.D., CIH of Wayne State University for their efforts in planning this conference.

Keynote Speaker

The Handicap Resulting from Noise-Induced Hearing Impairment

Alice Suter, Ph.D.

Alice Suter and Associates

To paraphrase Helen Keller, it is worse to be deaf than to be blind because blindness only cuts you off from things while deafness cuts you off from people.

Also, unlike vision problems, hearing impairment isn't readily apparent. People don't help you. Instead they often ridicule and humiliate you. "What's the matter? Are you deaf?" They would never do this sort of thing to a blind person. People often don't know what's wrong or why the hearing-impaired person doesn't respond or responds inappropriately. They tend to think the person is being rude or is intellectually challenged.

I'd like to take a few minutes to summarize the handicaps resulting from noise-induced hearing impairment. There are four categories: (1) the impact on communication, (2) the impact on self-esteem, (3) the effect on a person's interaction with their environment, and (4) the effect on intimate relationships.

Communication

Persons with noise-induced hearing loss will often have difficulty carrying on a conversation with their spouse, other family members, friends, colleagues, and anyone with whom they may interact. They will have trouble communicating with coworkers and understanding instructions.

They will often be able to "hear" but can't understand what is being said. Sometimes, in a quiet environment, the hearing-impaired person will be able to understand quite well. Communicating in a noise-filled room or when speech is not clear, however, will be much more difficult. This causes people to misunderstand the impairment. They may think that "he is just being stubborn" or that "she hears when she wants to hear."

The hearing impairment may result in violations of implicit social rules because it can be difficult to monitor one's voice level. Hearing-impaired people may talk too loudly causing embarrassment or too softly and not be heard.

It will be particularly hard for these people to follow the thread of conversation in a group. This is especially true in a noisy setting, which is typical of restaurants, taverns, club rooms, and even in a busy living room. Church rooms meant for socializing are notoriously difficult places for the hearing-impaired to communicate. Other examples of difficult situations are: (1) listening to TV and the radio; (2) communicating in the car, especially if the windows are down or if the radio is on; and (3) using the telephone. It is particularly difficult (or impossible) to use a pay phone because most pay phones are located outdoors near busy, noisy streets.

Self-Esteem

Persons with a hearing handicap develop a feeling of being cut off from others and what is happening around them. Their self-confidence will be affected because they feel unsure of themselves. They will become tense or tired from listening so intently, guessing, and filling in gaps in understanding. Many times they will either withdraw from the group or stay in the group and pretend they understand when they don't. The resulting isolation from friends and family, along with the stigma of hearing impairment, leads to depression and low self-esteem.

When an individual is hearing impaired he may wonder, if he cannot tell what is said, whether people are talking about him. Individuals who are especially sensitive will be afraid that someone is finding fault with them. If a group is laughing, the

hearing-impaired person may assume that people are laughing at him or her.

Environment

Certain everyday sounds in the hearing-impaired person’s environment may be difficult or impossible to hear. These include the doorbell, telephone ring, alarm clock, footsteps, water boiling, and a kettle whistling.

Another problem hearing-impaired people encounter in their environment is the failure to hear warning sounds. Sometimes this is merely an aggravation, sometimes a serious hazard. Some of the sounds hearing-impaired persons can miss are a door knock, car honking, car approaching a pedestrian about to cross the street, malfunctions in one’s car (scraping or whining sounds of malfunctioning brakes or bearings), smoke detector, coworkers conveying warnings on the job, sounds of machine malfunction, and auditory warning signals, especially in a noisy background.

Effects of Hearing Handicap on Intimate Relationships

Disruption of intimacy is probably the most serious consequence of a hearing handicap, yet it is seldom discussed, particularly by the hearing-impaired individual. Both husband and wife will suffer the consequences, which has been borne out by interviews with noise-exposed workers and their wives.

Studies by Hetu, Getty, and their colleagues show that the wives of workers report: (1) reduction of interaction with the hearing-impaired husband; (2) more negative behaviors on both parts, like short tempers, sarcasm, and passive-aggressive behaviors; (3) less satisfaction with the relationship; (4) communication that is less personal; and (5) reduction in the content of the communication, with only the most serious matters discussed because more casual conversation can take too much effort.

The normal-hearing spouse acquires what Hetu and Getty have called a “secondary handicap,” which is a

disadvantage resulting from having to adjust to her husband’s hearing impairment. This often results in stress, annoyance, frustration, and loneliness.

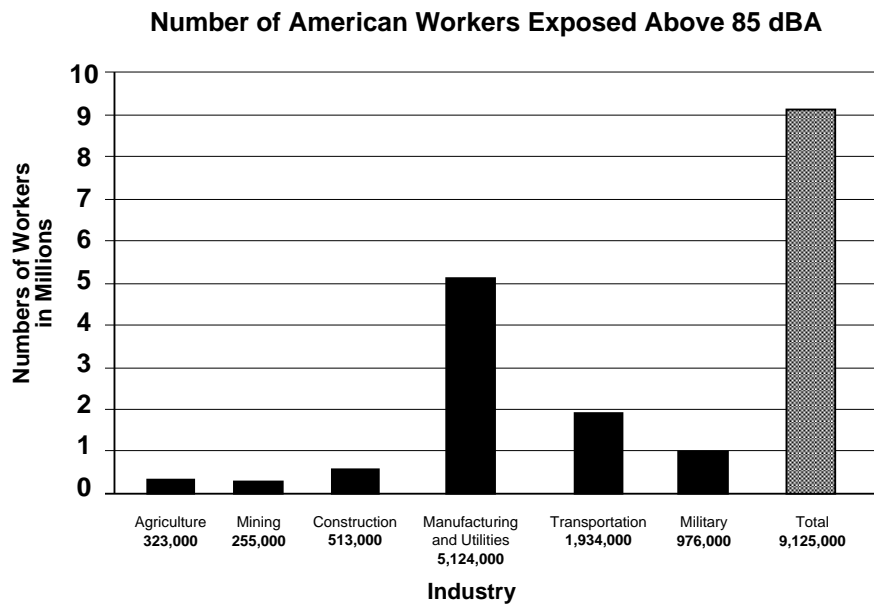
The hearing-handicapped individual generally does not want to talk to his wife about his difficulties and rarely acknowledges his wife’s secondary handicap. Solutions are seldom discussed, and the forms they take are often unsatisfactory. For example, the following actions may occur when the TV is too loud: (1) the wife endures high volume but is resentful, (2) the wife is driven out of the room, (3) the hearing-impaired person gives up trying to understand the show, or (4) the couple buy a second TV and they watch in separate rooms, which contributes to the isolation they both feel.

Another barrier to intimacy and self-esteem is that gender roles can change and an unhealthy codependence can result. The wife orders for her husband in a restaurant, interprets for him in a group of friends, makes his appointments, communicates with health care professionals, and may even take on legal and financial responsibilities. As a result, the hearing-impaired man may feel helpless, that his social status has been diminished, and become passive, having given over the responsibility of communicating to his wife. (Keep in mind that this can happen with women, as well.)

These are the things that hearing-impaired people won’t discuss, but if you sit down with the spouses, you find out about these problems.

Number of Workers Affected by Noise

Bolt, Beranek, and Newman collected data for the Environmental Protection Agency’s Office of Noise Abatement. The data were collected before 1981, when this office closed. The information obtained in this investigation represents the best available estimates of the number of American workers exposed to noise above 85 decibels, A-weighted (dBA) presented in time weighted average (TWA) exposure levels. The results from this investigation are shown at the top of page 5.



The table below gives information on the number of workers expected to incur hearing impairment over a working lifetime of 40 years. The exposure levels indicate that between 80-85 dBA there are 2.85 million workers exposed and 1 percent are at risk

based on 80 dBA. The next group use 85 dBA as the basis and the last group use 90 dBA, but because each group includes workers exposed above the lower level of that category, the estimated percentage risk is likely to be low.

Estimated Number of Workers in Manufacturing with Material Impairment of Hearing*

Exposure level in dBA	No. Workers	Percentage risk**	Potential No. with material impairment
80-85	2,850,000	1%	28,500
85-90	2,250,000	8%	180,000
>90	2,910,000	25%	727,500
Total			936,000

* Using the NIOSH definition of >25 decibels (dB) average at 1, 2, 3, 4k Hz over a working lifetime.

** These are likely to be underestimates because: (1) we are considering the whole 5-dB window rather than discrete levels, (2) all exposures above 90 dB are grouped in the >90 dB category, and (3) these apply only to manufacturing but do not include other professionals. On the other hand, they could be overestimates in that these are workers who are expected to incur noise-induced hearing loss if they work more than 40 years in this environment. There are many whose exposures are much less now, but if they keep working in a noise environment they will become hearing handicapped unless preventive measures are taken.

The Effects of Noise

In addition to a hearing impairment, another very serious safety problem occurs, and that is the masking of speech and warning signals. Studies have shown a connection between hearing loss and accidents, and this area is just beginning to be investigated more rigorously.

There is a huge body of literature on the effects of noise on job performance. In general, performance decrements are likely to occur at levels of about 95 dBA, especially when the worker is doing a complex task, in which case the more complex the task the lower is the level at which decrements occur.

There isn't a lot of research on the relationship between noise and annoyance and fatigue. There is, however, a lot of anecdotal evidence from workers who say that they feel much better, are not as annoyed, are less fatigued, and that they sleep better after a hearing conservation program has been instituted. There has been a great deal of research in the area of noise and general health, especially in Europe. This is a controversial topic, but there is much evidence that seems to indicate that levels of 85-90 dBA over a long period of time can cause adverse cardiovascular effects. Researchers believe that attitude also has an impact, especially where people have no control over the noise.

What Can We Do About the Problem?

First, we can focus on developing and improving hearing conservation programs. The necessary strategies include: (1) noise exposure monitoring, (2) engineering noise control, (3) audiogram testing, (4) training and education, (5) hearing protection devices, (6) record keeping, (7) evaluation, and (8) hearing conservation program evaluation.

Noise exposure monitoring and engineering noise control are considered together because workers need to learn what their exposures are and they need to be aware that their company is doing something constructive about the noisy work environment. Ultimately, they need to know that they will not have to wear hearing protection for the rest of their lives. Engineering control is the best long-term solution, and many would say the only one to resolve the noise problem.

In a good audiometric testing program it is important to keep continuity of serial audiograms. Audiometric testing by itself does not save hearing. It is only when the audiograms are evaluated in a serial process that they are useful in finding hearing that is beginning to deteriorate, prior to the situation where a great deal of hearing is lost. Otherwise, as Raymond Hetu has said, audiometry becomes "medical voyeurism."

Training and education are an extremely important part of the hearing conservation program, as workers need to know what the program is about and why.

Record keeping is essential for audiograms to be compared. It is especially difficult for workers in professions like construction, who move from job to job, to have previous audiograms available for comparison.

Evaluation of hearing conservation programs also is important. There is an American National Standards Institute (ANSI) standard for evaluating hearing conservation programs by comparing serial audiograms and using simple statistical measures. Unfortunately, most programs have been found to be ineffective when they are compared to the standard as a test. This indicates again the importance of engineering controls whenever feasible, as well as the application of other parts of the hearing conservation program.

Hearing protection devices involve a number of practical considerations as to whether or not they are worn. You would think that ensuring comfort seems like common sense. If a hearing protection device is not comfortable, it is not going to be worn. Compatibility with safety equipment is also important. Safety glasses can break a seal, and muffs may not attach well to helmets, decreasing the protective effect of the device. Attitude is also important. Does the worker think the hearing protector is a help or a punishment? Is there a macho attitude toward these devices? Hygiene is a factor because user-molded ear plugs are often rolled by workers with dirty hands who then place the devices in their ears. Proper selection in fitting makes a big difference as to whether or not the protector is worn. Each individual must be treated separately to find the best fit and the most appropriate attenuation for his

or her work environment. Communication and warning signals also impact the use of hearing protection devices. Professionals in audiology are very fond of saying the hearing protector will not interfere with and actually help you hear and understand spoken communication warning signals. In fact, this is not always true and these devices can hinder the perception of warning signals in some circumstances.

Problems with Hearing Protectors and Communication and Warning Signals

The most common problem is over-attenuation during low-noise periods. This is especially true within intermittent noise, which characterizes many industrial processes. The cross-over point between help and hindrance by a hearing protector is about 80 dB for people with normal hearing, but the level at which protection becomes a hindrance is higher for people with hearing loss. Persons with noise-induced hearing loss have a disadvantage because hearing protection devices provide more attenuation in the higher frequencies than in the low and mid-frequencies, yet noise-induced hearing loss is almost always worse in the higher frequencies. Thus the hearing protection device plus the hearing loss can render the signal or speech inaudible.

An article in *Spectrum*, the newsletter of the National Hearing Conservation Association, highlights the consequences of overprotection. Written by Gregg Moore, the article mentions Mead Killian, who developed the “musicians ear plug,” a device with attenuation that is uniform across frequencies. Killian, an eminent hearing scientist, musician, inventor, and entrepreneur is quoted as saying: “Who would buy sunglasses so dark that you couldn’t see cars coming down the road? No one. Who would buy ear plugs so effective that you couldn’t hear a forklift truck coming up behind you or a distant shouted warning? Everyone; at least every industrial buyer. We’ve trained them.”

Moore discusses the idea that bigger is not better. He emphasizes that overprotection is not a good idea and can lead to problems and accidents. In addition, it can lead to people cutting hearing protectors in half.

The result is that workers have the hearing protectors hang out of their ears. In other words, workers may wear hearing protection devices in such a way that they can hear communication but the hearing protector no longer protects their hearing. Moore goes on to say that hearing is critical for job safety. He indicates that we are doing an excellent job of impairing the worker’s ability to protect himself by “greatly impairing one of the two main senses for detection of warning signals—hearing. Not only that, we are also grossly impairing the sense primarily responsible for real-time communication among human beings—hearing.”

Another problem that is not often discussed is interference with the ability to localize. Both plugs and muffs can interfere with localization in the horizontal (right-left) plane and muffs can destroy localization in the vertical (up-down) plane. This is particularly a problem in industries like construction where workers often have to be aware of what is going on above them. Therefore, overkill is a very bad idea. Bigger is not better. Instead, hearing devices that have the right amount of attenuation for the conditions in which they are to be worn are needed.

Solutions

Possible solutions include the development of: (1) hearing protectors that can easily be taken on and off especially in highly intermittent noise; (2) protectors with uniform or flat attenuation, which are expensive but the advantage is well worth the money; (3) non-linear hearing protectors that let sound come through normally at low levels but attenuate at higher levels; (4) communication headsets with sufficient attenuation; (5) better warning devices for situations where workers need to hear the warning signals; and (6) noise control devices that provide workers with adequate protection so they can discontinue the use of hearing protectors.

Advancements in Europe

The European Union (EU) has issued many standards on noise including noise measurement, permissible noise limits, noise control, and labeling. The

construction noise directive put out by the EU mandates labeling of products used in construction. The label may include both sound power level and sound pressure level. American manufacturers who want to market in Europe need to have these kinds of labels. In addition, there is a program in Germany called the Blue Angel Program in which manufacturers can display a label indicating an environmentally friendly product, including low noise. There is a whole set of construction products

that display the Blue Angel label. Manufacturers have to go through rigorous testing and approval by the German government before displaying the label. Some American manufacturers have done this. These products are measured at a minimum of 10 dB below the required standard. Companies purchasing new products should demand from the manufacturer specifications for noise and products that are as quiet as possible.

Session I: Hearing Loss Prevention Program Evaluation Audit, Effectiveness, and Evaluation Measures

Ford’s Annual Report to the United Auto Workers (UAW)-Ford National Joint Committee on Health and Safety

Henry B. Lick, Ph.D., CIH, CSP
 Manager
 Occupational and Environmental Health Sciences
 Ford Motor Company
 Dearborn, Michigan

In many instances, employees have worn hearing protection the entire time they have worked. This is not acceptable. People who go to work for Ford or General Motors are going to work 30-35 years. We missed a big opportunity to prevent hearing loss in this country several years ago because we thought of noise control and hearing conservation as simply hearing plugs and muffs. Other prevention measures were too expensive. Ford has looked at noise control and hearing conservation several times but the various systems have usually been separate programs.

We have tried through the partnership with NIOSH, James Anderson Associates, Wayne State, and Hawkwa to develop a system that draws everything together. We call this HearSaf 2000. There are many elements in this program. The best thing about HearSaf 2000 is it allows you to measure your progress and see where you are going. That is the topic of discussion for this presentation. In addition, I will present a little about our annual report. This will be a valuable tool.

We have a noise control process that is a cooperative venture between Ford and the United Auto Workers. It has worked well over the last several years.

We are measuring worker exposure in a uniform manner in our process. We have in place a computer based audiometric testing system called Hear/Trak. It allows us to compare previous audiograms. It also can be used as a diagnostic tool and for teaching

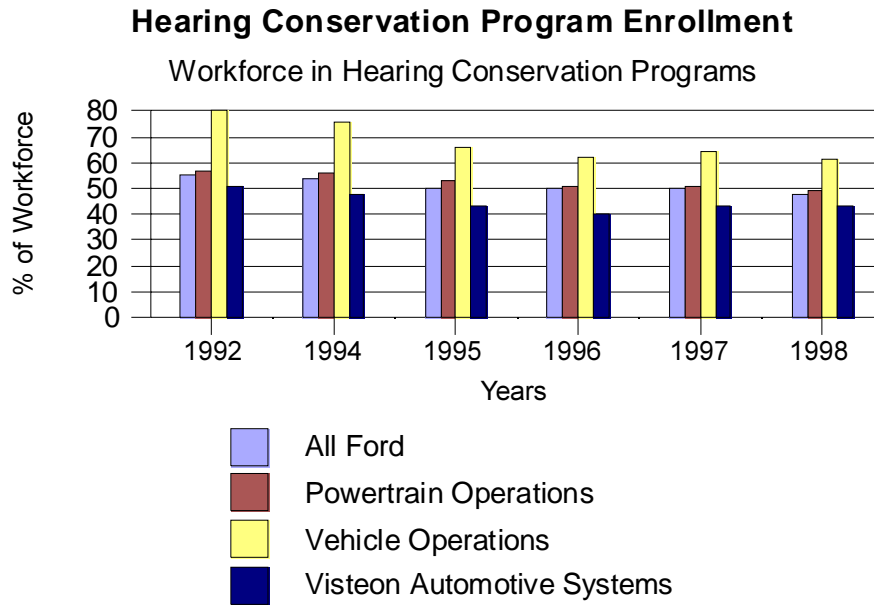
employees. In addition, it can identify noise sources within a manufacturing environment.

Ford Motor Company Program

A key part of our noise control and hearing conservation process is to buy-quiet. In addition, we measure exposures, and once we find problems, we try to make the equipment quiet based on priority. We also have audiometric testing and awareness as part of our noise control engineering process. The whole thing revolves in a business process.

At Ford Motor Company, we have a safety and audit system that we call the Safety and Health Assessment Review Process (SHARP) for accountability. One of the components in SHARP is the noise control and hearing conservation process. We also have a requirement for biannual noise studies. Finally, we have an annual report that documents our progress. We present this to the United Auto Workers Joint Committee on Health and Safety.

What is the foundation of our process? We use a task-based analysis system for our noise exposure monitoring. This allows us a standard of comparison and computer simulation. We can measure the cost-effectiveness of the different simulations. In the noise survey report, we include sound exposure risk from all locations.



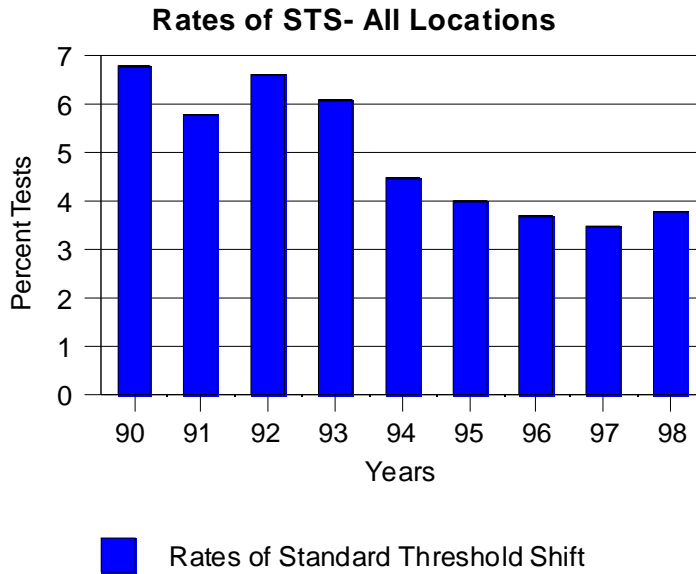
Note that in the above chart there are no data available for 1993.

Over the last several years we have moved more people into the 80-85 decibel (dB) levels as regards sound exposure. We enroll people in the hearing conservation program at 85 decibels, A-weighted (dBA). The number of people we have enrolled in this program has decreased over the years. This reduction in enrollment is a steady trend but not as dramatic as we would like. The graphic above displays these data.

In 1980 the auto industry didn't have a buy-quiet program. At Ford, we have had a buy-quiet program

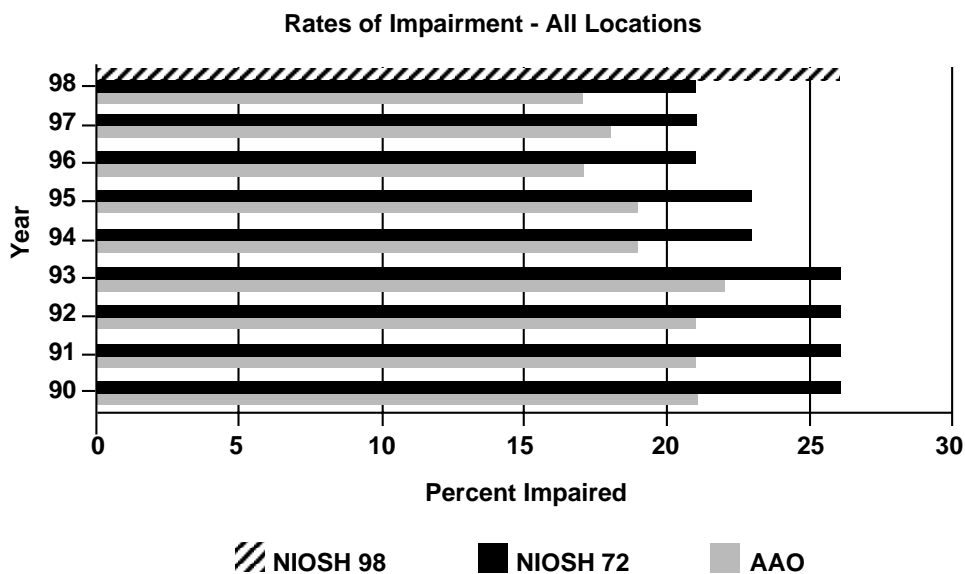
since 1990. This has helped us to reduce the number of people exposed to over 90 dBA.

As part of our process in our audiometric system, we track the rates of standard indicators like standard threshold shift (STS), rates of impairment, use of hearing protection, and employee training. Rates of impairment can be used to sell hearing conservation as a program to management. We went to our corporate executives and said that after 35 years they are giving employees a retirement gift of hearing loss. We used social responsibility to get their attention. The executives indicated that they did not want to do this to employees. As a result, we received support for our program.



Over the years we have had reduced STS rates as shown by the chart above. There were no changes in rates in 1996, 1997, and 1998. In this kind of situation it is important to make sure the program is not backsliding. This information gives you the impetus to go to management and make them aware of the problem. Hearing conservation and noise control really is a story of backsliding. The program does well for awhile, but it is costly. Someone says costs have to be cut and the program begins to backslide. Information like our Annual Report provides concrete data for management and prevents backsliding.

The data shown below represent rates of impairment. Our 1990 numbers were kind to us because we were just beginning our program. We compare our impairment rates to the NIOSH and American Academy of Otolaryngology (AAO) criteria. The NIOSH criteria are more conservative than the AAO criteria, particularly the 1998 NIOSH criteria. Even when rates are adjusted by age, the rate of impairment is about 150,000 employees. The rate of impairment is going down.



Main Elements of the Program

The main parts of our noise control engineering process are to buy-it-quiet and keep-it-quiet. If everyone is included in making the choice for buy quiet, it may stay quiet. If maintenance is not available to keep it quiet, this is where the program fails.

In conclusion, the value of regular benchmarking helps to adjust the process on an annual basis and

keep the process on the right track of progress. People are afraid of programs like ergonomics and hearing conservation because they are costly. If you don't have a roadmap, however, to measure what you are doing, you don't know where you are going. The process we use helps us to know where we are going.

Web-Based Self-Audit Protocol and Effectiveness Measures in the Military

Doug Ohlin, Ph.D.

Manager

U.S. Army Center for Health Promotion and Preventive Medicine
Aberdeen, Maryland

Over a year ago, the U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM) purchased Web-based self-assessment software specifically designed for the Army's hearing conservation program.

There is a little-known Fed CFR 1960.79 requirement to perform annual self-assessments of local programs. Federal laws do not apply to federal agencies unless they are specifically mentioned as in the aforementioned law or made to do so by executive order. An executive order signed by Jimmy Carter in 1980 made the Occupational Safety and Health Administration (OSHA) applicable to federal agencies.

When OSHA does an inspection, they collect all company self-assessments. Understandably, this has a chilling effect on doing self-assessments. A notice has been recently issued for comment that OSHA will not request self-audit reports when it does an inspection if a voluntary self-audit has identified a hazardous condition and has taken corrective measures. OSHA will treat this as evidence of good faith and not a willful violation.

For the last 15 years at the corporate level, we have had procedures in place for assessment of the hearing conservation program. At the installation level we have had them in place for 12 years. This past year these reporting capabilities have been interrupted as we convert to tri-service reporting systems.

Years ago we went on site and conducted "program surveys." Such evaluations were not always welcomed. Today, these programs are so minimally staffed, and the last thing people in the field want is

for someone to come out and tell them about problems they already know they have. They want help. When we go on site now it is to emphasize direct assistance.

Even when local and corporate reporting capabilities are in place, there is a need for a management tool to evaluate areas not covered by audiometric or industrial hygiene data. Self-assessment software had the obvious appeal of being self-administered with minimal cost. We needed an application that included unique military program requirements. The outcomes should be reproducible with limited intra-user variability, track issues to closure, and be user-friendly, requiring minimal advanced software product training.

My vision as program manager also included the benefit that this software could be used to educate field action officers on program requirements. We have great difficulty getting over burdened staff to read program documentation updates and implementation manuals. Hopefully, this application would be a way to painlessly learn and implement program requirements.

Our vendor had software on the general management of occupational safety and health that identified five levels of program implementation. Army hearing conservation requirements were adapted to those five levels (see table on the next page). To avoid duplicative language, each level should be understood to include all positive factors contained in the category immediately below it. One of the shorter questionnaire sections Program Evaluation is discussed on the next page.

Program Levels

Level	Percent	Level of Hearing Conservation Program
1	20	No program or ineffective program
2	40	Developmental program
3	60	Basic program
4	80	Superior program
5	100	Outstanding program

Program Evaluation

At what level (1, 2, 3, 4, or 5) is a program evaluated?

1. Little or no collection of data or analyses of program outcomes are conducted. Audiometric database is so corrupted by poor record keeping practices that reports only yield quality assurance shortcomings.

Few of our programs should be at Level 1. We started collecting data in 1980 following a successful Air Force model. From 1980-1987, we only reported measures of program participation and quality assurance. It wasn't until data acquisition in the field became automated that we were comfortable reporting measures of program effectiveness.

2. Poor program participation limits the value of program effectiveness reports. Reports are not forwarded to command and medical leadership on required schedules.

3. Program participation reports are staffed through the installation medical authority to the installation commander quarterly for "no shows" and annually for overall monitoring audiometry compliance. Quality assurance reports are forwarded to the medical authority at least twice a year including earplug fitting distributions, types of hearing protection issued, and negative standard threshold shift (STS). Program effectiveness measures are reported through channels at least annually and include prevalence of positive STS, military hearing

profiles, and potential civilian hearing loss compensation.

Level 3 includes the basic requirements for the Army's program evaluation criteria. No doubt, common ground is shared with other programs. One unique Army requirement could be reporting earplug-fitting distributions. We have two preformed earplugs that come in different sizes, and we have ways of monitoring how they are fitted out in the field.

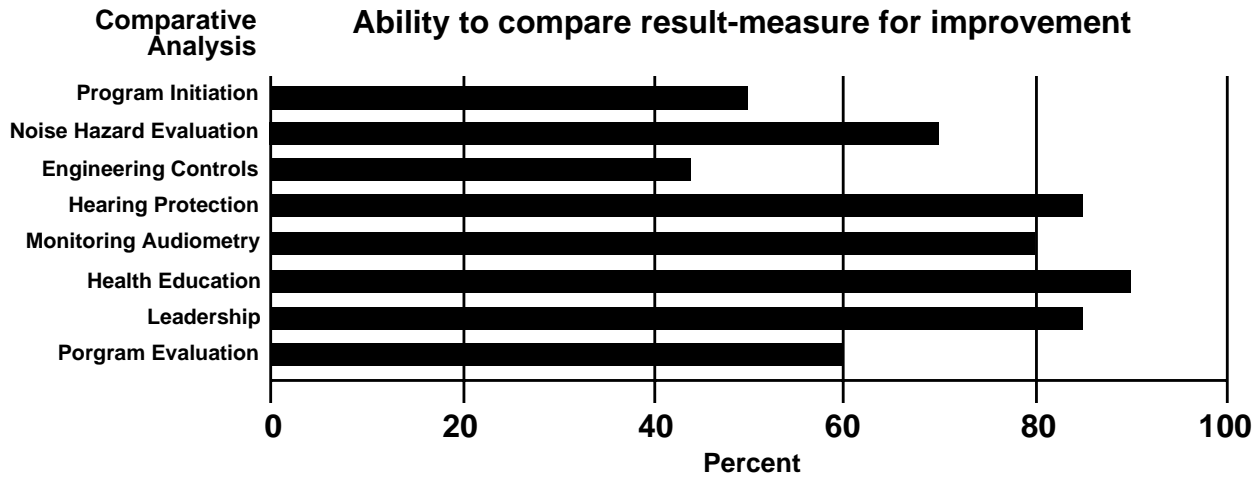
4. Reports are forwarded with uncluttered, color graphs when appropriate and written with concise, nontechnical language for the "uninformed reader." The most severe problem areas, high-risk areas, and high-risk job classifications are readily identified. Program participation is reported at the unit and shop level.

Level 4 represents mature programs staffed by highly skilled personnel. It should probably go without saying that reports should be written for the uninformed reader.

5. Epidemiological studies, e.g., relative risk assessments with matched groups, are conducted. All levels of command and the workforce are aware of monitoring audiometry compliance and prevalence of positive STS.

Level 5 will probably be representative of a successful multidisciplinary approach. Note that some of us think that program evaluation should be along the lines of relative risk assessment and a focus

Performance Measures



on the individual. The proposed ANSI standard focuses on the data. We would like to see the proposed standard adapted for quality assurance applications. Epidemiological statistical models have been shown to be more reliable for assessing program effectiveness.

Another feature of the software is the ability to graph results and compare over time measures of program improvement or deterioration. The graph above displays performance measures.

Although unproven at this point, our new self-assessment software holds the promise of a low cost management tool that can educate program administrators, document proven implementation strategies, chart program progress, and provide program evaluation coverage in areas not covered by audiometric or industrial hygiene data.

NIOSH Criteria Document Effectiveness Measures

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When we put together the NIOSH *Occupational Noise Exposure Criteria Document*, we included hearing loss prevention effectiveness evaluation as Component 8. I want to discuss Component 8 and what we recommend people consider doing to evaluate programs. There are two levels in our Component 8 concerning evaluation of effectiveness. The first is evaluation of effectiveness at the individual level and the second is evaluation at the program level.

Before you can measure the success or failure at either of these levels, you must have an environment where achieving success is possible. This depends on the workers and the employers. We want workers to adhere to corporate policies, participate in noise control and abatement programs, wear hearing protection devices, show up for hearing tests, and attend training.

What Does Management Need to Do?

It has to enforce its policy all up and down the line. A buy-quiet policy is necessary. Barriers to get to quiet work areas and to hearing protection must be removed so workers and managers don't have to fight the system. Management needs to stress the importance of the hearing testing and provide relevant, interesting training.

Effectiveness measures: In the 1990s the corporate safety culture is retiring and new corporate members are entering who are not part of the system as partners. One of the consequences of this is that new workers are receiving injuries, acquiring illnesses, and, in a few cases, being killed because of failure to use safe work practices that are second nature to the older workforce.

Evaluation

Individual effectiveness: A hearing loss prevention program's effectiveness is best demonstrated by having no workers suffer occupational hearing loss. To reach this end at the individual effectiveness level, NIOSH recommends that audiometry be conducted at the end of the work shift. The search is for temporary shift, and the immediate goal is to prevent it. If you find temporary threshold shift and prevent this, then permanent threshold shift is much less of a problem than it would be otherwise. Once temporary threshold shift is identified, the person should come back for an additional test to determine that temporary shift is not there. In this situation, while the loss is still temporary, you can respond to the problem before the worker experiences a permanent threshold shift. It is also necessary to search for common errors; retesting helps to rule these out and to assure accuracy. In addition, to do anything with individual effectiveness, audiograms must be reviewed. Workers need to get instant feedback to make the program important. If these steps are not followed, the company will have a big hearing loss program instead of a prevention program. Each audiogram is a marker of how effective the program is for an individual and the audiogram must be managed aggressively if occupational hearing loss is to be prevented.

Programmatic effectiveness: In terms of overall evaluation, data must be collected to identify trends in the workers and then to identify problems in the system before permanent threshold shift develops due to problems in the work setting. The evaluation has two parts: (1) coming back and looking at the database already collected to make sure it is accurate

and (2) comparing the data to existing other standards as external verifiers of effectiveness. As an example, Draft ANSI standard S12.13 uses existing databases, does year to year comparisons, and charts comparison percent of audiograms in year to year for the same people. It also calculates the percent of workers with a 15 decibels (dB) change in hearing threshold for a frequency range of 500-6000 Hz. We look in the older group for the percent that have gotten better or worse. The standard says whether your program is acceptable or not. It gives you confidence.

We also are looking at the internal integrity for a person. We are trying to find unconfirmed threshold shifts, unsupported baseline audiograms, noise levels in audiometric tests booths that are too high, large differences between the good and bad ear, and large adjacent frequency differences. In this case we are calculating the external comparator. This is done using sequential audiograms to calculate standard threshold shifts (STS). Company employees who are not exposed can also be used as the comparison group. Another way is to compare your data to standards that provide statistical populations. The

one we have in the United States is ANSI S3.44, an embodiment of the ISO standard with the addition of one database to round it out. Database A is highly screened with audiograms for males and females with no hearing problems collected by Robinson. Database B has audiograms for unscreened (noise exposure) males and females. It is more like a population database. Database C has audiograms for black and white males and females and is a domestic database with different prevalence rates.

Conclusions

Basically, for these kinds of effectiveness measures, you must start first with the right kind of corporate culture, one that has zero tolerance for occupational hearing loss. Subsequently, we can look at individual effectiveness and provide instant feedback of audiogram results and prevent permanent threshold shift by identifying and responding to temporary threshold shift. We can look at program effectiveness by assessing the integrity of data and the use of comparison to external criteria such as local non-exposed workers or to statistical populations.

The Contribution of Focus Groups in Evaluation of Hearing Conservation Program (HCP) Effectiveness

Mary Prince, Ph.D.

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My talk today will focus on: (1) the context of a larger research study, (2) focus groups as a research and evaluation tool, and (3) how we use focus groups in this ongoing study at NIOSH. I would like to recognize the researchers, including my coauthors on this paper, Michael Colligan and Raymond Sinclair. I would also like to mention B.J. Bishoff, who conducted the focus groups.

The purpose of our study is to identify factors associated with effective hearing conservation program practices and also to develop indicators to measure effectiveness. Briefly, the study includes three noise exposed groups whose data will be compared to other low noise exposed reference populations. We are trying to identify audiometric data sources that have a large number of low noise exposed employees to do the comparison.

In general, the study systematically evaluates each component of a hearing conservation program using data collected according to the OSHA Hearing Conservation Amendment to the Noise Standard. A checklist scores programs as proactive or compliant. I will discuss this checklist later and how we use this in the study with focus groups.

We collect data from multiple sources from company records including noise exposure, audiometric data, according to company policy/procedures, training programs, and management practices. We also are collecting training materials, doing one-on-one interviews with trainers using an evaluation checklist, and conducting focus groups.

Formal surveys can be used as well as employees. People often wonder why formal surveys are not the only tool used for evaluation. Most people want to put a survey in the mail and get employee feedback. This quote sums up why qualitative research is important.

“Quantitative measurements are quantitatively accurate; qualitative evaluations are always subject to the errors of human judgements. Yet it would seem far more worthwhile to make a shrewd guess regarding that which is essential than to accurately measure that which is likely to prove quite irrelevant.”

LaPiere, 1934

Focus Groups

Focus groups are an accepted method for collecting qualitative data. They are appropriate when assessing needs or professions or evaluating programs. They have the advantage of providing data through a social interaction. Thus the data have higher validity than survey methods. The focus group moderator guides the discussion and probes participants when answers are not clear and need to be amplified. The moderator fine tunes the collection of data as it occurs. This flexibility helps to insure the quality of the data. Focus groups, further, are faster and less expensive than surveys. However, the drawback is that they provide less generalizable data in comparison to survey data. Usually no statistical tests are conducted and samples are small and not randomized. However, forgoing the representativeness of the data, focus groups provide a rich cultural understanding about the workplace that is not accessible by quantitative means.

In this study, focus groups are employee centered and attempt to explain the effectiveness of training efforts from the workers' perspective. Issues covered include the workers' perception of the company commitment to the worker hearing conservation program. The managerial practices that contribute to these perceptions are explored. The extent to which hearing conservation training themes are transferred to and reinforced in the workplace are assessed. The

workers' feelings about the strengths and weaknesses of the hearing conservation program are also elicited. I am not going to discuss how focus groups have been recruited for this particular study. We plan four focus groups per company with about 10-12 participants per group. Two of the groups will include first line supervisors and two groups will be composed of hourly employees. Workers represent a variety of job classifications to characterize historical changes in the nature and quality of hearing conservation programs at each site. Only employees who have been enrolled in the program for ten years or more can participate. Every effort has been employed to have a demographic profile and department distribution of recruited workers similar to the plant population. The focus groups are conducted by a trained moderator. The moderator is kept blind to the hearing conservation details about the program. Meetings take up to two hours and are held off site. Participants are paid \$50 as an incentive to cover travel cost and time.

We start by asking participants what sort of health issues are important to them at their plant. This allows us to get an idea of where hearing health falls in the range of health concerns. It also gives us insight into their baseline awareness of hearing as a health issue.

We are interested in how hearing practices have started over time. We ask participants to tell us how the program started and describe how they were tested. We also ask about hearing protection used in terms of compliance as well as what is taking place with regard to noise monitoring and engineering controls. We typically pick a reference point; something happened in the plant or a time point near to the time when the OSHA standard was implemented. For companies with no formal audiometric testing before the standard was put in place, we try to look at more recent history compared to when the standard started. For other companies, we will have information prior to the standard to compare.

With regard to training and communication, we are interested in their perspective on the types of training they have received. What types of training have they liked in the past? What types of training would they like increased?

We are also trying to get information on perceived barriers that employees have about wearing hearing protection, whether employees understand the current plant policy, and how the employees view the current plant policy as regards enforcing hearing protection. Finally, they are asked about their perception of company commitment to protecting their hearing. Employees are asked, "What does your company do to protect your hearing?"

Program Evaluation

The big question is how we use this information in program evaluation. The short answer is that it is one piece of information we use. Furthermore, it helps in fine tuning some of the other information we collect from the evaluation checklist and from other sources of data. The program evaluation list will be used to categorize each of the three components of the overall program.

In this study, the evaluation checklist and structured interviews are conducted with administrative personnel responsible for the training and other aspects of the training prior to the focus group sessions. The responses provided by the administrators of these programs from these two instruments are compared to data collected during focus groups. This functions as a check for consistency and enhanced insight regarding administration of the program elements from the employees' perspective. The degree to which component and overall program scores differ with and without employee input from focus groups can be examined to check for consistency and components that need special attention. In our analysis, we can then examine how well this correlates to: (1) hearing loss over time, (2) noise exposure over time, and (3) trends in hearing protection utilization.

We have found, thus far, that focus groups (if well conducted) offer some special opportunities. Focus groups conducted in off-site locations provide a more relaxed environment for employees to share their insights on program effectiveness. This setting is also an opportunity to probe informal training on issues that arise during the sessions. For one facility, NIOSH investigators, at the suggestion of the plant safety and health manager, provided a half-hour

training session. It focused on questions that came up during the sessions on hearing health issues.

Use of Focus Group Information

One of the ways that information from focus groups can be used is to generate a list of frequently asked questions. These frequently asked questions can be posted on health and safety bulletin boards, Web sites, and used during individual and group training sessions at the plant. Focus group results can also be disseminated to all employees to increase awareness of hearing health issues and provide other employees, who were not able to participate in the focus groups, the opportunity to provide input. Information obtained from focus groups in combination with a survey allow for more active input in hearing conservation efforts at the plant.

Health and safety managers may use information on employee perception of the effectiveness of current training to develop more innovative training materials to fulfill employee and plant needs. Focus group discussions on the perceived barriers of using hearing protection can provide information for program evaluation follow-up. For example, workers can identify noise sources such as air leaks due to malfunction in equipment or the lack of maintenance. Follow-up investigations can then be conducted to evaluate the feasibility of noise control measures.

Safety issues related to employees being able to hear warning signals when wearing hearing protection may be valuable information for evaluating the hearing protectors that are being provided for employees. As a follow-up measure, the types of protection used by employees can be evaluated to

reduce over or under protection, given an employee's hearing status. Moreover, quality of the employee and safety personnel communication can be assessed in the focus groups.

Summary

Focus groups provide a structured, interactive, and relaxed atmosphere for discussion of a variety of topics regarding hearing loss prevention efforts. The added dimension of respondent interaction and discussion as a check on the generalizability of individual responses during the sessions is a dynamic data gathering technique. Surveys assure us that within defined margins of error we know how the populations respond to the narrow questions they have been asked.

On the other hand, focus groups help to assure us that we are asking the right question. Qualitative data from focus groups are particularly valuable in program evaluation when used with other sources of data. Focus groups, one-on-one interviews, and other qualitative techniques allow us to follow up on answers in a structured way. In addition, similarity of responses across focus groups and consistency of responses with other sources are a reality check for administrators to gauge program effectiveness. Focus groups are useful for gathering information missing from records. This includes company commitment and the corporate safety and health culture. Finally, focus groups can be used by program evaluators to bring in employee ideas for improving the program, which hopefully brings increased employee buy-in and increased commitment to hearing prevention efforts.

Session II: Regulation, Surveillance, Compliance, and Enforcement in Hearing Loss Prevention

Project Sensor: Hearing Loss Surveillance

Ken Rosenman, M.D.

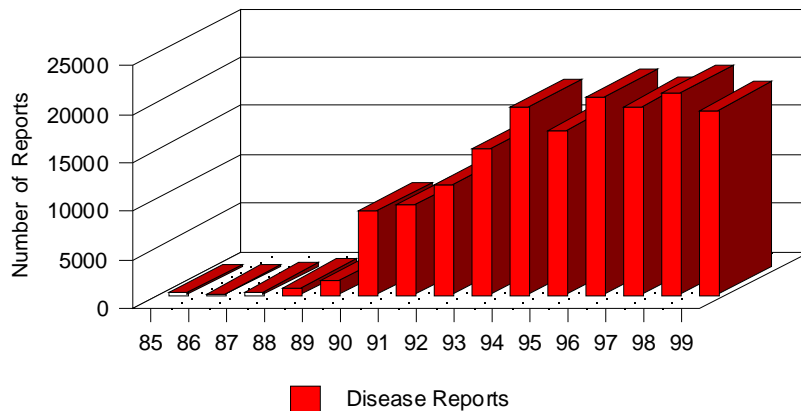
Professor of Medicine
Michigan State University
East Lansing, Michigan

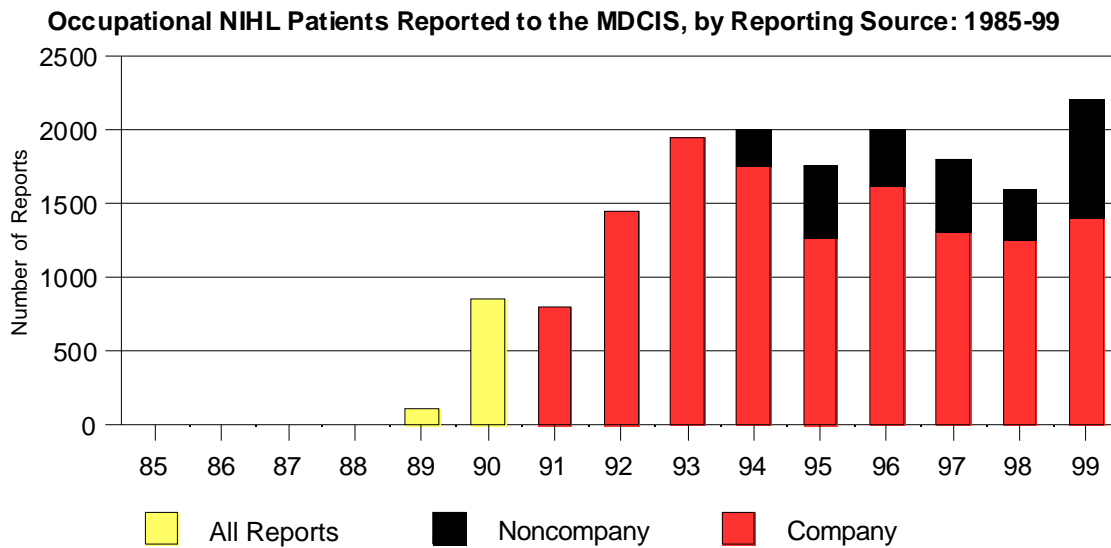
I am going to talk about the Michigan Work-Related Noise-Induced Hearing Loss Surveillance Program. In response to the need for more information on the occurrence of occupational illness, the National Institute for Occupational Safety and Health (NIOSH) developed the Sentinel Event Notification System for Occupational Risks (SENSOR). This is a competitive program to encourage states to conduct occupational disease surveillance. Michigan has received funds since 1988 when it was funded for silicosis and asthma. In 1992 work-related noise-induced hearing loss was funded through this program. Approximately a dozen states receive funds to perform occupational disease surveillance. Michigan is the only state that has received funds to do surveillance for noise-induced hearing loss. The program is jointly administered by the Michigan Department of Consumer and Industry Services (MDCIS) and Michigan State University.

The disease reporting for noise-induced hearing loss is based on the 1978 Michigan law that requires all employers and individual health practitioners to report all known or suspected work-related diseases.

The number of occupational disease reports is shown in the graph below that have been recorded since the state began to receive funding from NIOSH in 1988. Musculoskeletal, respiratory disease, and hearing loss are the major conditions reported. There are about 20,000 reports received per year in Michigan of which 1800 or so are noise-induced hearing loss. The noise-induced hearing loss reports are for both temporary threshold shifts and fixed loss. Even though the total number of reports received in 1999 will be slightly less than in 1998 (estimate shown on chart), the number of reports for noise-induced hearing loss has increased as is indicated by the graph at the top of page 22.

Occupational Disease Reports to the MDCIS: 1985-1999





1999 projected data are based on cases reported January-August 1999

The reports of noise-induced hearing loss from non-company physicians are increasing. We are encouraging this activity. These noncompany reports are being submitted on workers who are not part of any hearing conservation program. We know there is a large amount of underreporting. This underreporting can occur at varying stages. Using data from NIOSH’s National Occupational Exposure Survey (NOES), we estimate there are approximately 200,000 people in the state with noise exposure greater than 85 decibels (dB).

The chart on the top of page 23 shows the surveillance program for noise-induced hearing loss in Michigan. To be entered into the state surveillance system, the individual has to have had a hearing test. We don’t know how many people have audiometric testing, but even if someone has work-related noise-induced hearing loss on audiometric testing then whoever is doing the testing has to submit a report in order for the case to be in the surveillance system.

Since 1992 we have received 12,000 reports of work-related noise-induced hearing loss. The report comes into the state. The individuals with the fixed loss are interviewed. Their workplace will be inspected if the following criteria are met:

- (1) the person was exposed to noise in the last five years, (2) the noise was not intermittent, (3) the

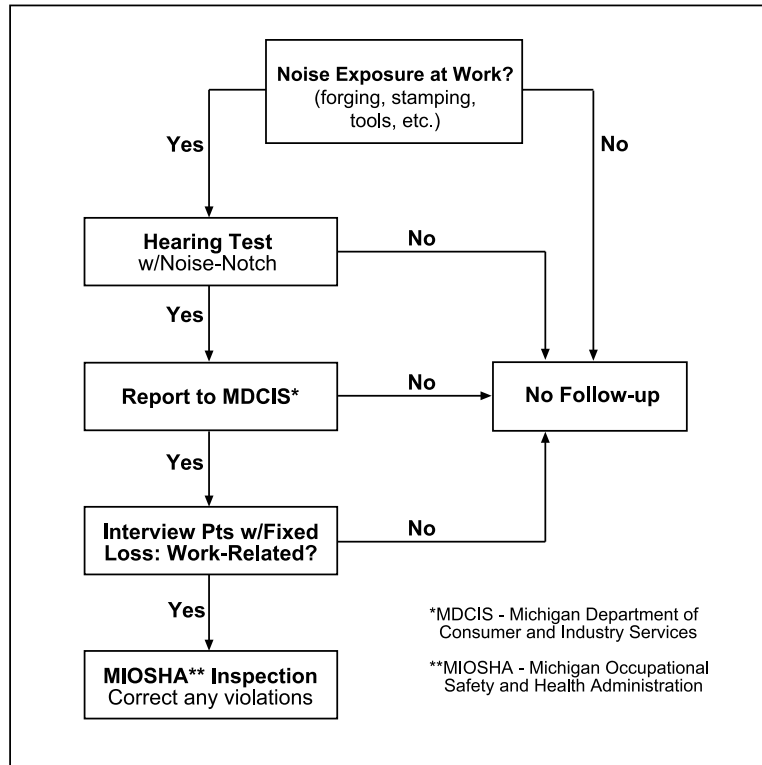
workplace is covered by the Michigan Occupational Safety and Health Administration (MIOSHA), (4) there is no regular audiometric testing, and (5) workers are not required to wear hearing protection.

If the worker says “no” to regular audiometric testing and “no” to being provided hearing protection, then at least in the worker’s perception they are not part of a hearing conservation program. About 60 inspections have been done under this program. We have received 12,000 reports, interviewed about 1800 people, and completed 60 inspections. I’ll come back to the results of the inspections later. The inspections are done as MIOSHA enforcement inspections.

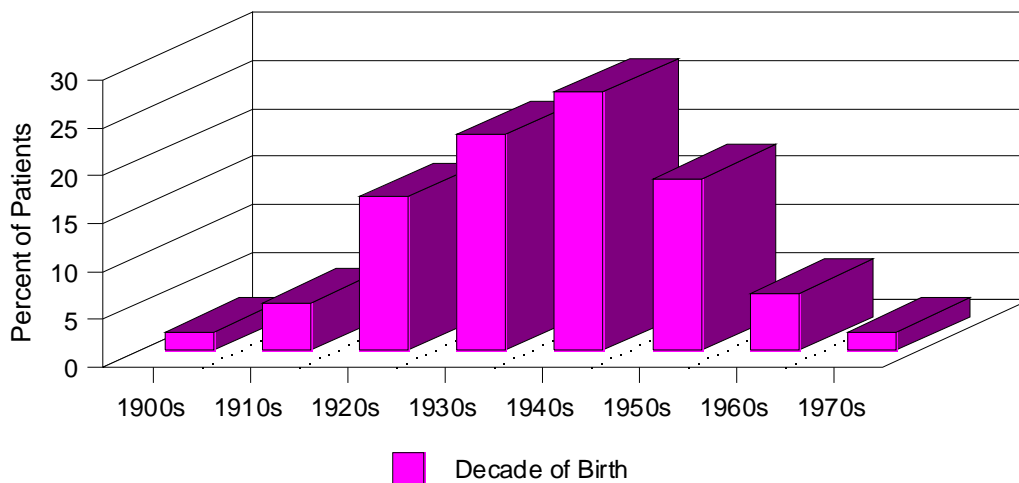
Just to say a little about the people recorded: most of the workers reported with a standard threshold shift (STS) are still working. For individuals with fixed loss, about 70 percent are elderly and retired and are being reported by private practitioners in the state, which is shown in the graph at the bottom of page 23.

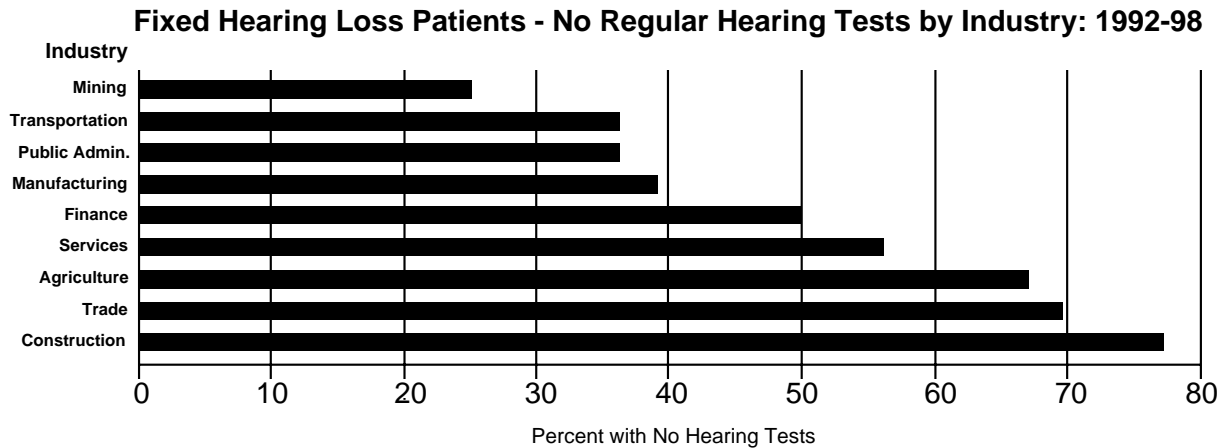
Of the people who have been reported, over 90 percent are men and over 90 percent are white. If we look at where industry people are coming from, approximately 50 percent are in manufacturing, 10 percent in service, 10 percent in construction, and 10 percent in transportation have fixed loss.

Surveillance of Occupational Noise-Induced Hearing Loss in Michigan



Decade of Birth of Patients with a Fixed Hearing Loss: Michigan 1992-1998



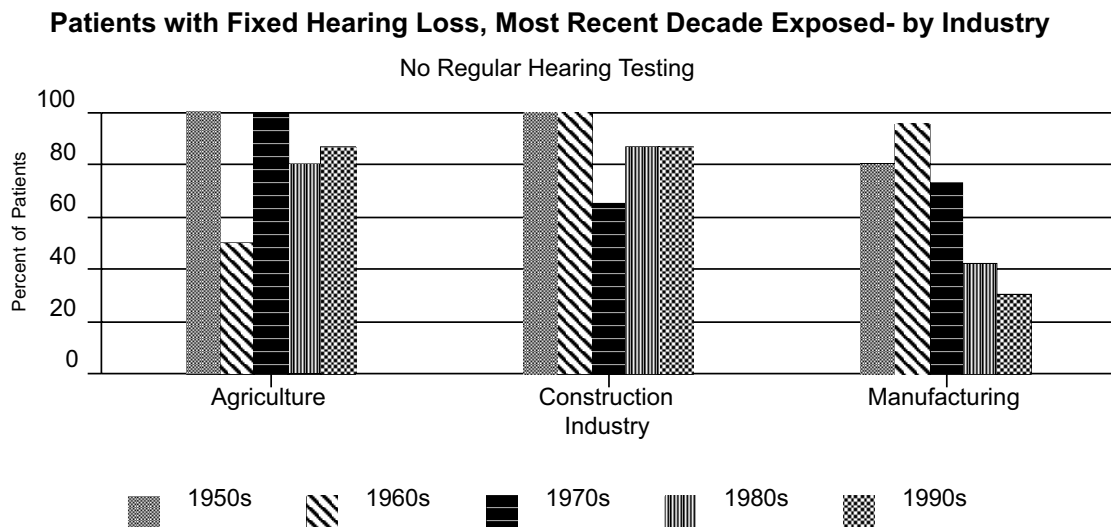


Industries where audiometric testing is not required by OSHA regulations do not provide a hearing testing program on a regular basis, as shown by the graph above.

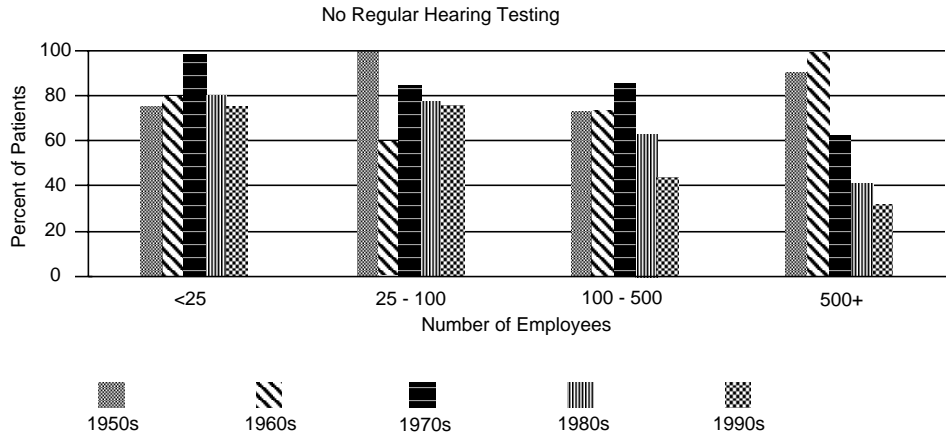
increased in the last 30-40 years, as indicated by the data shown below.

If one compares agriculture, construction, and manufacturing, only in manufacturing has the percentage of workers receiving audiometric testing

Approximately 30 percent of people working in manufacturing in the 1990s reported with fixed loss indicate they were not provided regular hearing testing. Although this percentage is high, it is a clear improvement from the 1950s to the 1990s. This is not the case in agriculture or construction, where no such improvement is seen.



Decade Recently Exposed to Noise, Percent Fixed Loss, by Company Size, 1992-98

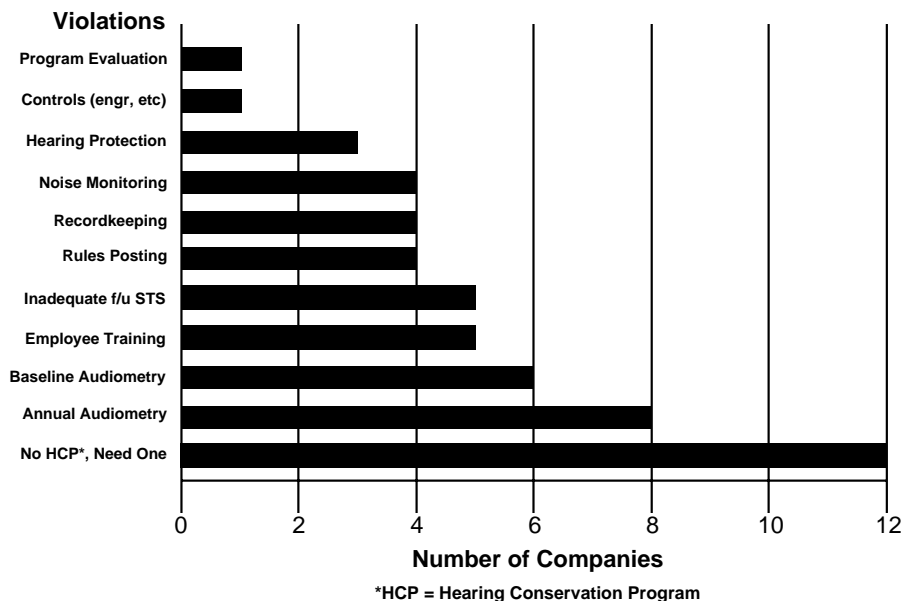


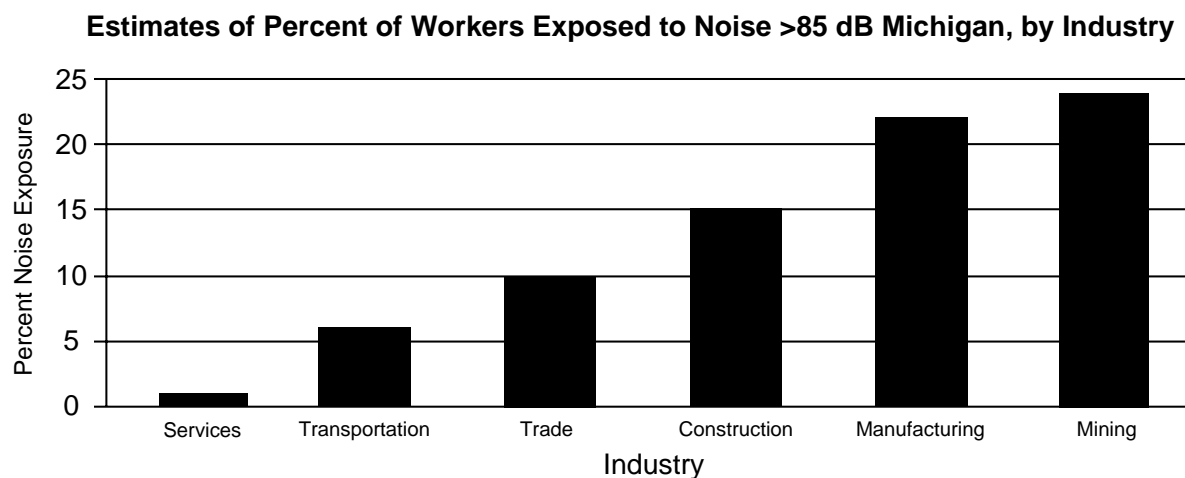
Large and medium size companies have done a better job providing audiometric testing (see above chart).

There were 60 companies that were inspected following a fixed hearing loss. There were 34 (57 percent) companies with a high enough level of noise that required a hearing conservation program. Using our criteria from the interview results, 57 percent of the time we correctly identified companies with higher than 85 decibels, A-weighted (dBA) time-weighted average noise exposure. Of those 34 companies, 24 or 74 percent had no or a deficient hearing conservation program. The bar graph below displays data for companies inspected as a result of noise-induced hearing loss interviews with employees. Twelve companies had no program. Of

the companies that had some form of hearing conservation program, the deficiencies noted included: eight had no annual audiometry, six had no baseline audiometry, and five had inadequate employee training. Other citations were five had inadequate follow-up of STS, four had no rules posting, four had deficiencies in record keeping, four had deficiencies in noise monitoring, and three had deficiencies in hearing protection. One was cited for lack of noise controls and one was cited for no program evaluation. A total of 4000 workers exposed to more than 85 dB in these 24 plants where at least some deficiency was found in the hearing conservation program benefitted from these inspections.

Companies Inspected from NIHL Interviews, Michigan 1992-98 Noise Violations





Summary

We know that in terms of surveillance we are getting the tip of the iceberg. We get reports from 15 percent of the otolaryngologists and audiologists. We assume the remaining 85 percent are seeing patients with work-related noise-induced hearing loss but are just not reporting.

The data above show estimates based on the NIOSH exposure survey of the estimated number of workers exposed to greater than 85 dB in Michigan. The services industry has only a low number of people represented. This is because of the method used to conduct the survey. NIOSH only surveyed certain Standard Industrial Codes. Based on the NIOSH survey, up to 200,000 workers are exposed to 85 dB or greater in Michigan. I would consider this an underestimate as NIOSH did not include all types of industries. The National Health Interview Survey Data is a random sample of the general population that is surveyed on a regular basis. The percentage of people with hearing loss is recorded. We estimate based on this national survey that in Michigan there are approximately 86,000 people with work-related fixed hearing loss. We know we need to do more to encourage reporting.

I am concerned about the number of people we need to interview to identify companies where we suspect an inadequate or absent hearing conservation program in an industry regulated by MIOSHA and where an inspection is initiated. We interview 30 people to identify one company where an inspection is initiated. People are being reported with work-related noise-induced hearing loss and exposed to noise in situations not regulated by MIOSHA. The noise may be intermittent or it may be in an industry where the regulations do not require a hearing conservation program, such as in construction.

Our interviews with workers exposed to noise in construction reveal that almost no one gets their hearing tested (96 percent do not) and that over half (58 percent) are not provided with hearing protection. We know noise exposures on these types of jobs can be over 100 dBA with some equipment (NIOSH has conducted measurements). Further, a significant percentage of the workers in construction with hearing loss have been exposed to noise in construction for relatively short durations (22 percent exposed to noise in construction for five or fewer

years). Regulatory changes are needed to require the construction industry to provide a hearing conservation program.

We need to do more educationally for other industries where noise is intermittent. The inspections that have been done following up an index case are useful and protect coworkers from noise exposure. Our inspections at this time have been limited to identifying companies that should be providing a hearing conservation program rather than identifying companies with excessive standard threshold shifts and addressing the adequacy of their hearing conservation programs.

I want to encourage any of you who should report and have not done so. The information below shows several ways to report a case:

Ways to Report Cases of Known or Suspected Occupational NIHL in Michigan

- Fax: (517) 432-3606
- E-mail: Rosenman@mus.edu
- Call MDCIS for OD Report Form: (517) 322-1608
- Call MSU: 1-800-446-7805
- Access the Web site: <http://www.chm.msu.edu/oem>

An annual report that contains the information discussed today can be found on our Web site, www.cdc.gov/niosh.

Strategic Planning for Reduction of Noise-Induced Hearing Loss in Michigan

Doug Kalinowski, M.S.

Deputy Director, Bureau of Safety and Regulation
Michigan Department of Consumer and Industry
Services
Lansing, Michigan

The Michigan Occupational Safety and Health Administration (MIOSHA) started a strategic planning process that includes noise-induced hearing loss. Throughout FY98 and FY99, we worked on developing a strategic plan that was created to focus our resources. The basis of this was the federal Government Performance and Response Act. We presented the draft strategic plan to stakeholders and asked for input. We explained the plan and asked these stakeholders to indicate if we were on target. Most people agreed that hearing loss was a very important issue.

There are three strategic goals: (1) improve workplace safety and health as evidenced by fewer hazards, reduced exposures, and fewer injuries, illnesses, and fatalities; (2) change workplace culture by increasing worker and employer awareness of commitment to and involvement with safety and health to affect positive change in the workplace culture; and (3) secure public confidence through excellence in the development and delivery of MIOSHA's program and services.

One of the basics of the strategic plan is measuring results, not just activities. Is there an impact on workers? Is hearing loss reduced? This relates to strategic goal number one. In developing specific strategies, we used 80 people in the Bureau of Safety and Regulation to determine how to react to these issues, including noise-induced hearing loss. We are going to target specific Standard Industrial Codes (SICs) for enforcement as well as outreach. Data from the Sentinel Event Notification System of Occupational Risks (SENSOR) project will be used to assess impact, although we recognize that these data may not be ideal due to current underreporting. In Michigan, the process is resource neutral.

One of the things we plan to do for noise-induced hearing loss is better training for our safety

investigators in evaluating noise exposure and hearing conservation programs. Up until this time, our safety officers did not carry sound level meters. We recently did training for our safety officers so that they can evaluate sound levels before a referral is made to the health side.

There are two outcome measures: (1) primary—reducing the noise-induced hearing loss in Michigan and (2) intermediate—the number of violations or hazards identified associated with noise-induced hearing loss. If fewer violations are identified, a reduction in noise-induced hearing loss should result. Data sources and issues that have to be settled internally have to be resolved in the process.

Strategies for Implementation of Strategic Goal Number One

The strategies for implementation of strategic Goal 1 are to:

- (1) Distribute information packets to all establishments from selected SICs.
- (2) Perform occupational health training seminars to employers in targeted SICs on noise induced hearing loss.
- (3) Conduct occupational health on-site consultations in targeted SICs.
- (4) Schedule occupational health compliance inspections in establishment in selected SICs.
- (5) Conduct some follow-up inspections in subsequent years.
- (6) Distribute information to all services providing audiometric testing.
- (7) Form partnerships with trades, associations, and local health and safety councils.
- (8) Prepare, distribute, and publish hearing conservation articles.

Twenty-four Standard Industrial Codes were identified for a focus on noise-induced hearing loss. These include lumber and wood products, furniture and fixtures, primary metal industries, and fabricated metal products except machinery and transportation equipment. These groups have the highest percent of employees exposed to noise and the highest number of employees.

Other parts of the strategic plan that relate to strategic goal number one include two other injuries (amputations and overexertion/repetitive motion) and other industries with elevated injury and illness rates. Five specific industries (meat products, nursing and personal care facilities, metal forgings and stampings, fabricated structural metal products, and construction) are also addressed as part of strategic goal number one.

Pending Revision to CFR 1904 Recordkeeping Rule

Jim Maddux

U.S. DOL

OSHA Directorate of Safety Standards

Washington, D.C.

Before I address several hearing loss issues, I would like to mention the OSHA third party audit policy. This has been a big issue in various legislative proposals over the last few years. We have just proposed a new policy for dealing with third party audits during an OSHA inspection. This is an issue for hearing loss professionals because many employers use reports from noise consultants. If you have an interest in this issue, the policy can be found on the OSHA Internet home page and you can provide comments to OSHA to help us craft our policy.

We have not yet issued the Final Occupational Injury and Illness Recordkeeping rule. We plan to release it in 2000 and implement on January 1, 2001.

Recording occupational hearing loss is an issue in that rule, but it is one of a 100 recordkeeping issues. It has been a hotly debated issue for many years. In 1991 OSHA came out with a policy stating we would only cite employers when they failed to record 25 decibel (dB) shifts from a pre-employment baseline audiogram corrected for aging.

In the 1996 Notice of Proposed Rulemaking (NPRM), we proposed recording when the worker experiences a 15 dB shift. We got a lot of comments on:

- (1) The amount of hearing loss that should constitute an OSHA recordable illness.
- (2) The determination of work relationship.
- (3) Whether the audiograms should be age corrected.
- (4) What baseline to use.
- (5) Whether or not a worker could have more than one hearing loss over their period of employment.

We received a wide range of comments on all those issues. For the recording level, most commenters supported either the 10 or 25 dB shift.

We are trying to come up with a reasonable recording of hearing loss that will provide the basis for the

nation's statistics on this issue. The statistics right now are inconsistent and not very useful. The Bureau of Labor Statistics (BLS) data on individual characteristics of injuries and illness provide information only on those cases that result in days away from work. Occupational hearing loss does not usually require days away from work, so there are very few occupational hearing loss cases showing up in the BLS data. Less than 100 cases per year are reported. Therefore, we are trying to find a consistent recording method that will give us more useful data while minimizing false positives. We need to find a middle ground that will give us some good information.

Another point to consider is that the Mining Safety and Health Administration (MSHA) published their rule for occupational noise exposure in mines last month (September 1999). It covers a broad range of issues, hearing protection devices, and audiometric testing. It also addresses the issue of recordability for hearing loss in mines. In the MSHA system, recording and reporting are one and the same. Mine operators have to provide MSHA with ongoing reports of workplace injuries and illnesses as they occur. The new MSHA standard requires mine operators to report cases at the 25 dB level using a pre-employment audiogram. It also allows a correction for aging. MSHA has come out in their final rule at the same recording level we are currently using for OSHA enforcement, the level we decided not to use in our proposed rule.

The other thing I would like to mention is our effort to deal with noise in construction. The current OSHA rules have separate OSHA standards regulating noise and hearing conservation in construction versus general industry. The construction standard is a minimal standard when compared to our general industry standard. It does not require a full hearing conservation program and does not give many details about what such a program would involve. For example, there are no

requirements for audiometric testing or employee training.

In the November Regulatory Agenda (1999), we announced an advanced notice of proposed rule making (ANPR) for OSHA to start working on a revision of the construction noise standard. It will only be an ANPR and not a full notice of proposed rulemaking. An ANPR asks the public to comment on a series of questions concerning whether and how

a standard should be pursued and the issues addressed, which may lead to a proposed standard in the future. There are different issues in construction in terms of baseline audiograms and annual audiograms because of the rapid employee turnover rate in this industry. We want to deal with all the issues related to noise in the construction industry in a fair way. When we publish our ANPR for noise in construction, I encourage everyone to comment and give us feedback on this important issue.

Breakout Session I.

Noise Measurement and Noise Control

Organizing a Noise Control Engineering Program

Robert Anderson

James, Anderson & Associates, Inc.
Okemos, Michigan

This presentation will focus on the organization of a noise control program.

Introduction

In the 1970s, it was an exciting time to be a noise control engineer. The OSHA Noise Regulation was just enacted and there was much enthusiasm within the engineering community to search for solutions to noise problems. With the early engineering advances and the support of the major employers, we believed we could engineer quiet workplaces in our lifetime and thus prevent hearing loss in our workforce.

Here we are 30 years later. From available statistics, we know noise has been reduced in the workplace, but there are many noisy processes for which commercial controls were developed in the '70s that are still noisy today. Most disturbing is the fact that the incidence of hearing loss in workers has not substantially changed since the '70s. Today one may visit any workplace and see workers in high-noise jobs not wearing their hearing protection correctly or not wearing it at all. What has happened in the last 30 years?

Some argue that the OSHA regulation actually lowered the bar for engineering excellence by specifying exposure limits. Some argue that the Hearing Conservation Amendment took the wind out of engineering initiatives by providing an alternative approach to protecting the worker.

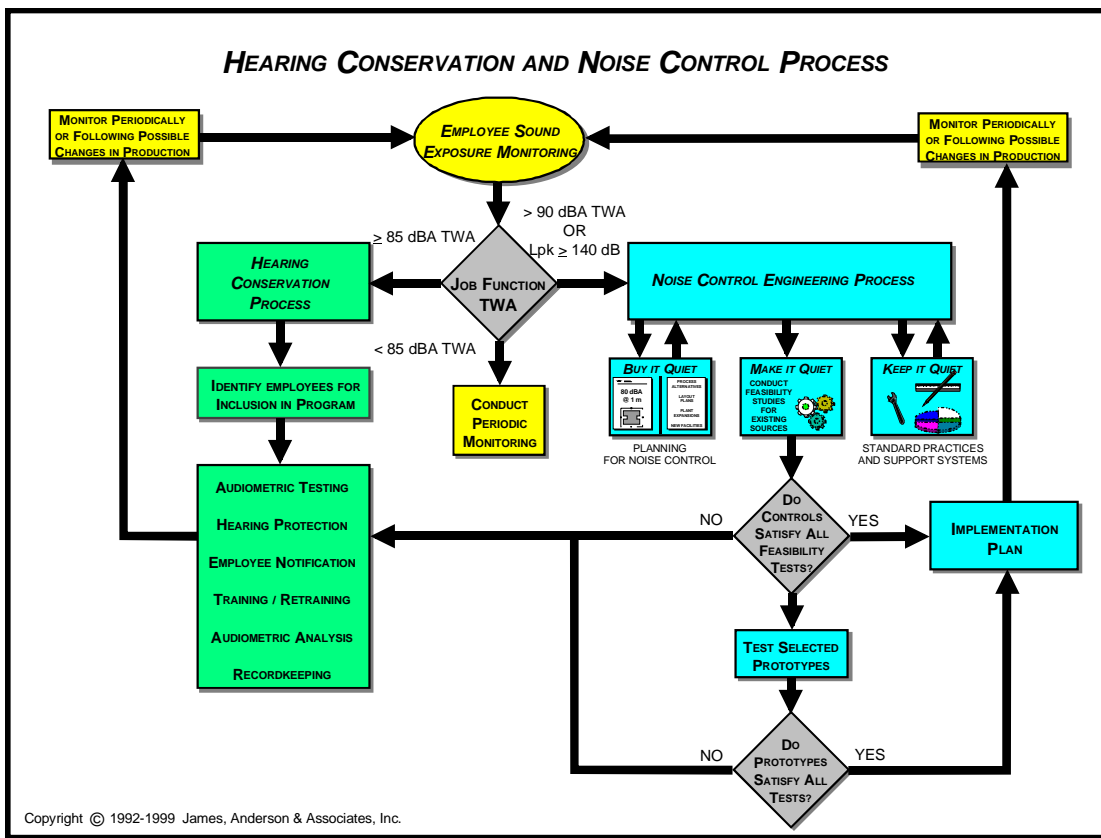
Whatever the reason, we know that we have not yet achieved our goal of hearing loss prevention in the workplace. Today we would like to explore some of

the elements in noise control engineering programs that have worked. These findings are from over 20 years of studying and working to perfect large industrial programs. One thing we can conclude is that worker awareness and involvement is essential in a successful hearing conservation and noise control program. As you participate in this presentation, I ask you to think of how worker awareness fits into each of these elements.

Hearing Conservation and Noise Control Process

The successful hearing loss prevention program has to include both engineering and hearing conservation elements. We are going to concentrate on the noise control engineering aspects in this discussion. I would like to say that the noise control engineering programs that are successful are the ones that approach achieving their goals in much the same way a business would approach its business goals. For example, if a business such as a manufacturing company wants to produce a new product, there is a specific decision-making process for this. Those companies that have been successful in their noise control engineering programs have adopted aspects of their business process into the programs.

Secondly, I would like to say that successful noise control programs are acknowledged as and



approached as processes. That is, rather than having the specific beginnings and endings that are associated with programs or “find and fix” approach, the approach toward noise control is planned, implemented and monitored in a cycle. This is because unlike many other worker hazards, noise is intimately connected with the process, machinery, machine condition, work practice and worker.

The above chart shows the hearing conservation and noise control process. Everything revolves around an exposure survey with decisions based upon exposure risk (whether workers are included in a hearing conservation program) or decisions involving engineering control. Overall program goals aim to:

- Eliminate noise-induced hearing loss in all workers.
- Improve the work environment.
- Comply with all regulations.
- Keep management involved and informed.
- Evaluate and justify resources to keep the process cost-effective.

Let’s look at the process elements.

Process Elements

There are three process elements:

- 1. Noise control planning**, including making sure that new equipment that comes into the facility has a noise level limit (this is usually done by strict purchase specifications).
- 2. Control of existing noise sources** by the use of a methodology for identifying and classifying problems, determining feasible controls, developing an implementation plan for their elimination based on priorities, accountability, time benchmarks, and documenting action.
- 3. Ongoing noise control** through standard maintenance action and management support for people like engineers or those who can adopt standard practices into their maintenance jobs that don’t take direction from engineers. For example, skilled tradesman can take noise control into account when building sheet metal systems.

If we fast-forward this process into the future, quiet equipment continues to be introduced, there is a

specific strategy for addressing existing sources, and the workforce is habituated to standard noise control practices. As a result, we will have an organization that is more aware, with more people taking responsibility for noise reduction as part of the job.

Strategies

Let’s look at strategies in more detail.

1. Buy-it-Quiet

This element considers noise control in the future of the organization’s operations. Its purpose is to evolve quiet operations and practices into the organization. Equipment, whether new or rebuilt, should be purchased under a noise specification, which results in the quietest equipment for the money spent.

The purpose of the noise specification is to put the responsibility for engineering of new equipment on the manufacturers and suppliers of equipment. This means that control measures are designed into the equipment at the manufacturing level. An equipment specification that limits the sound level to 80 decibels A-weighted (dBA) at a one meter envelope around the equipment is standard in the automotive industry and other large companies. The specification has the option for the plant to refuse to accept delivery of equipment generating sound levels above that specified level. The noise level limit applies to a full load condition. A complete specification can also include noise limits for the community and office.

Secondly, there should be purposeful planning for equipment layout. The layout of the equipment has

implications for noise. Also, the implications of noise during any change must be considered. Is noise part of everybody’s job or is it one person’s job? Successful programs intend to integrate noise responsibility into everybody’s job.

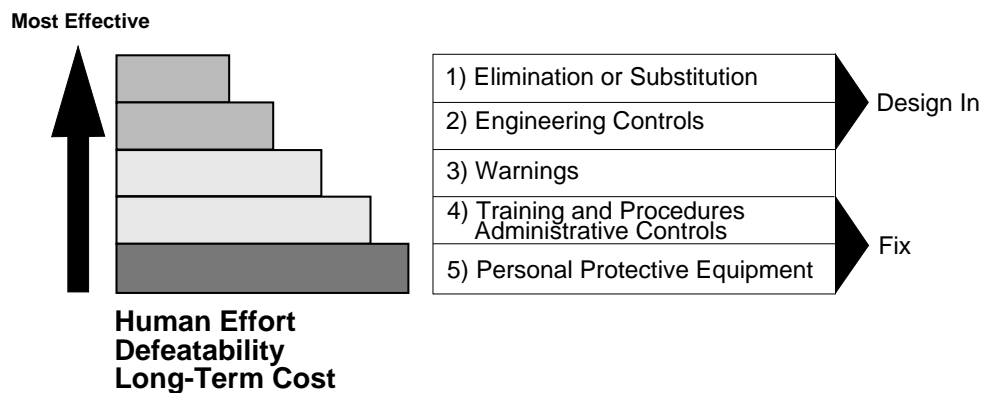
2. Make-it-Quiet

This second element of the process addresses those noise sources currently in the workplace. It involves a method to identify sources, to determine if there are “feasible” controls, and to establish a plan for implementation. If you have participated in projects to reduce equipment noise, you know a methodology is necessary. From a business standpoint, it makes sense to know the implications of controls in terms of cost and benefits. This can be achieved methodically by conducting feasibility studies to determine major noise sources that affect workers, classifying these sources as to whether there is feasible control, developing an explicit plan for implementation, and then monitoring the plan.

Proper exposure monitoring identifies the problems. Often exposure monitoring yields only one number that is used to assess risk. Data related to the conditions and major noise sources are very useful to direct the next step. Monitoring methods such as Task-Based Exposure Assessment Modeling (T-BEAM) are useful in providing additional information. In conjunction with review of monitoring data, a floor inspection will identify common noise sources. The impact of each source on workers can then be identified.

In summary, we start noise source identification from our exposure monitoring and field inspections.

Hierarchy of Health and Safety Controls



They help identify the factors needed to establish the priorities in noise source evaluation. Now, what would be the criteria for establishing priorities? They might be the jobs where exposure risk is over 90 dBA or over 85 dBA, or the number of workers exposed or based on the number of complaints received.

The Hierarchy of Control chart on the previous page is based on the standard principles of hazard elimination and is shown in the order of greatest effectiveness and highest priority. Designing in elimination or substitution is expected for new purchases. In terms of current noise sources, we obviously want to look at elimination or substitution as the most desirable control, with external controls such as enclosures being lower in the hierarchy. Controls like administrative controls and personal protective equipment are external to the operation and have the greatest possibility for being defeated.

After the noise sources are identified and their impact on workers is known, a noise control feasibility study is conducted for each source. Noise control options that may be applicable for each source are reviewed. Sources of information include experience, equipment manufacturers, noise control applications specialists, and noise control experts. Based on the review, the sources can then be classified into three categories: feasible, not feasible, or indeterminate. Now the question is, what is meant by “feasible?”

A working definition of “feasible” has evolved from cases within the U.S. courts dealing with the issue of noise control engineering. The definition involves two tests related to technology and economics, and a test for significant benefit to the worker. To be classified as “feasible,” the control must satisfy all three criteria.

The tests for feasibility include:

A. Technical Feasibility—The control measure is commercially available, it can be applied to the specific problem, it has been used with success in the same or similar applications, and the impact of introducing the control into present operations is reasonably understood.

B. Economic Feasibility—The initial and recurring costs of the controls are defined and considered reasonable for the benefit achieved. Here we must

know initial costs and recurring costs (annualized), replacement cost, production penalty, and maintenance costs.

C. Benefit to Worker—The control measures will reduce the overall worker noise exposure level significantly. This could include the following results:

- Exposure levels will be reduced to below 100 dBA time weighted average (TWA).
- The control measure will reduce worker exposure by 5 dB or to less than 90 dBA TWA.
- The control measure will reduce worker exposure level to less than 85 TWA, the level to which hearing protection is designed to protect.

Examples of sources with feasible controls include compressed air or maintenance items, which have commonly accepted treatments. Examples of sources where there are no feasible controls might be process related where they may be resolved with new equipment. Indeterminate sources may have a solution, but this is not known. These sources may require further study. In some cases it may be advantageous to implement a control measure that does not meet all the above criteria. Any noise control measures that do not meet the criteria could be considered experimental or prototype measures.

After the sources and controls are categorized, an implementation plan can be formulated. Noise sources correctable by feasible controls are scheduled for treatment. A written plan documents the organization’s commitment to implement engineering controls. A well-documented plan includes a description of the activity, name of person assigned with responsibility, and a schedule with completion dates.

3. Keep-it-Quiet

The third element of the process is the “safety net” of the system. It consists of standard work practices by skilled trades and a support system that uses a reporting scheme to maintain oversight of the entire process.

Standard work practices involve training and authorizing maintenance staff to address noise hazards as part of the job. Many noise problems are

the result of compressed air use and leakage, poorly designed material handling equipment like chutes and tables, and maintenance issues like lubrication, tool sharpness, belt tightness, and alignment. Training skilled-trades staff to recognize these hazards and to apply standard control measures, especially in material handling and enclosure construction and design, results in integrating noise control activity into the job. It further increases awareness for noise control opportunities. Over time this ensures that progress made through quiet equipment purchases and implementation activities is preserved. This also helps to habituate the workforce to integrate noise control into the daily activity, which makes noise abatement efforts process-based rather than project-based and gives the effort longer life and long-term support.

The other aspect of the support system is a common system of reporting, which puts this information into a language that people who are directing the program can understand. This usually involves a committee to help communicate the message.

Noise Control Committee

A Noise Control Committee can be a very effective way of directing the noise control process. However, a key to its success is the allocation of individual

responsibilities for the program to specific committee members. We have often seen committees get bogged down when all committee members make all noise control decisions. To avoid this problem, we recommend that the committee be represented by those people who are responsible for each program element and that the committee as a whole meet to direct and track progress. Typically, members can consist of health and safety representatives, engineering, medical, maintenance, and production. Each permanent member should be responsible for maintaining a specific element of the process.

To ensure the elements of the process are functioning as intended, indices of effectiveness should be defined and tracked. We need to know if we are getting better or worse. The indices should be documented regularly and in the language that management understands. Measures of program effectiveness include sound exposure risk trend, standard threshold shift (STS), rate/impairment rate trends, hearing protection use trends, audiometric test progress, awareness training initiatives, and engineering benchmarks.

This has been a brief description of how to organize a noise control engineering program based on our experience in studying industrial programs and helping companies to develop their own programs.

Noise Control on a Budget

Stephen I. Roth, P.E.

Roth Acoustical Associates

Pittsburgh, Pennsylvania

In 1971- 1978 I was asked to implement the noise control program for the aluminum industry in Pittsburgh. I have been in business for myself for several years.

Benefits

In this session we will discuss the benefits of a low noise workplace. Noise control is a tough sell. Often it is difficult to sell a noise control program on the basis of the reduced hearing loss risk alone. Let's name at least eight good reasons to have a low noise workplace at your facility:

1. Increased safety. It is difficult to hear warning signals in high noise. Unfortunately, wearing hearing protection may make it more difficult to hear warning signals, especially for hearing impaired workers.
2. Increased productivity. Workers can do their jobs more efficiently in comfortable working environments.
3. Meet OSHA requirements; it is the law.
4. Reduced workers' compensation liability costs.
We are seeing significant payments to workers.
5. Reduced worker annoyance and increased morale.
6. Improved communication.
7. Reduced worker stress.
8. Improved maintenance and product quality.

I cannot stress enough the importance of getting your management to understand the real value of a low noise workplace.

Goals

Often noise control seems like "black magic;" noise controls are implemented but results are not as good as expected, or are unclear. There is an approach to doing noise control that I am recommending for your facility.

1. You have to set an appropriate goal.
2. You have to determine the noise source. For example, is the problem the fan or the motor driving the fan?
3. You have to analyze the noise sources and determine what techniques and materials will control the noise.
4. You have to calculate the results and determine the estimated costs of noise control.

Management will not buy into a program without knowing what the reduction is going to be and what the costs will be to carry it out. You have to have competent people to determine the needed controls, estimate the costs, get the funding, and implement the controls.

What should the goals for a noise control project be when you want to minimize the cost associated with the program? In most cases, setting a goal of meeting worker eight-hour time-weighted averages [possibly an eight-hour time-weighted average of 85 decibels A-weighted (dBA)] will be appropriate and allow for reasonable noise control solutions. Sometimes companies will want to get the noise level down to 85 dBA at three feet from every piece of equipment in the plant. This may be quite expensive and too restrictive. You should set a goal to protect the workers yet allow for economically acceptable solutions.

What about the goal of removing all ear protection in an area of a plant or for the entire plant? A company sometimes says it will not spend funds on noise control in the plant unless it can remove all hearing protection. This is not an appropriate philosophy as most noise reductions, especially over 3 dBA, can reduce the risk of worker hearing loss even if they continue to wear hearing protection.

Choosing the appropriate goal is very important and affects the cost of your noise control project.

Analyzing Noise

It is extremely important to understand the noise level associated with the worker’s job, and it is important to prioritize noise levels so you know where it is best to spend money. We conducted noise level tests on various aspects of a worker’s job in a plant. We looked at all the noise sources that affect an operator’s position and determined the noise levels shown in the table below:

All Sound Measurements at Operator Positions

Operator Position	Sound Level dBA
Trim Saw	99.2
Chute Air Exhaust	98.3
Cut-off Saw	94.3
Automatic Grinder	92.3
PA System	91.1
Drag Motor	88.2
Puller	83.4
Table Movement	82.4

In this situation, we had a trim saw that caused a lot of noise (99.2 dBA). It is interesting to note, however, that people complained about the noise from table movement. Obviously, table movement is not an issue of great importance in this situation, and you would not spend much time to resolve it. It is extremely important to make sure you understand the noise level associated with the job tasks. If you want to reduce the time-weighted average of the worker, then strive to resolve the problems with the highest levels of noise. When you have a noise source that is 10 dBA below another noise source, you won’t get any benefit out of resolving the lower level noise source. You are wasting your time if you work on the low noise sources; make sure you understand the noise sources and work on the high noise sources.

When you analyze noise you have to look at frequency. Most of the noise that affects the A-weighted noise (dBA) is associated with the high frequency part of spectrum 1000-8000 Hertz. Very often, resolving the high frequency part of the spectrum will be beneficial in reducing the risk of

worker hearing loss. In fact, the controls to reduce high frequency noise involve lighter weight materials, less thickness of absorptive materials, and less cost. You must conduct a noise frequency analysis and compare the attributes of the materials you are going to use in doing noise control engineering. When you have to deal with lower dominant frequencies, you are generally involved in more expensive systems, heavy walled enclosures, thicker materials, etc.

Noise Control Products

When we discuss economical noise control opportunities, damping techniques provide excellent noise reductions at relatively low cost. If you have a hard material (castings, ore, even small items such as pharmaceutical tablets) hitting another hard surface (chutes, diverters, product bins, etc.), you will have significant noise. If damping material is placed on the outside of the surface that is being impacted or incorporated in the structure of the surface, reductions of 5-15 dBA can be achieved. The impacting material never comes into contact with the damping material itself, providing long material life, and the cost of this product can be as inexpensive as \$3-5 per square foot. When dealing with heavier surfaces, you need to use thicker damping materials, in constrained configurations. Damping works for plates, hoppers, and chutes, etc.

Cushioning is another way to cut noise economically. To cushion, use rubber, plastic, or another appropriate resilient material placed between the impacting material and the surface it is impacting. You can get reductions of 5-20 dBA for \$10 per square foot of material cost. This will not work for products with sharp edges or if the product is too hot. It works very well in the mining industry and for parts buckets, ball mills, material chutes, vibratory feeders, and screening devices.

High pressure air noise is prevalent throughout industry and provides opportunities for low-cost remedies. If you use high pressure air blow-off for ejection, cleaning, cooling, etc., use the lowest air pressure possible, place nozzles as close as possible, and purchase “quiet” nozzles. You can get 5-15 dBA

reduction in noise using these techniques. Pipe away air exhausts to a remote location or to a properly vented hollow member or use large air exhaust silencers to prevent clogging, which can result in unacceptable back pressure on the system. Larger is better with silencers.

Finally, when designing machine guarding in your safety programs, go one step further and incorporate noise control materials to reduce noise to your workers.

Conclusions

1. Noise control engineering in the workplace is best addressed as an ongoing process. Project-based approaches to noise control tend to be ineffective

due to the pervasive and chronic nature of many noise problems and the perception that the noise “project” will have a finite conclusion.

2. The practices of consistent, regular sound exposure monitoring to monitor exposure risk is valuable to monitor effectiveness of control activity.

3. The process should involve safety personnel, engineers, medical staff, workers, and plant management working together.

4. A successful program integrates noise control into a business process using business language and terminology to make noise control issues part of the common business systems of the facility.

Breakout Session II: The Role of Audiometric Data Management in Hearing Loss Prevention

This session featured three presenters focused on different aspects of using audiometric data collected in the hearing conservation program.

Audiometric Data: Use It, Don't Lose It!

Thomas Simpson, Ph.D.

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Wayne State University
Detroit, Michigan

The key is to use your data. Hearing conservation programs result in large amounts of hearing test data, but the tendency is to do the analysis required by law and no more. Compliance-based reports are typically generated, but there is little impetus to look more carefully at the data to detect trends, meaning that many things go unnoticed.

- **Are appropriate people receiving hearing tests?**

Sometimes people have been overlooked who should have been tested because only the test output was reviewed and no further quality assurance was carried out.

- **Plot changes over time.**

Metrics, like standard threshold shift (STS), can be used to see how the program is performing.

Discussion on draft American National Standard ANSI S12.13-1991 led to description of year-to-year comparisons in hearing threshold as indicators of program and data viability. This process can help to determine the consistency and reliability of the audiometric data and provide indication of the appropriate level of confidence in other analyses of the data.

Access to software to aid in this kind of audiometric analysis is not readily available. Obtaining the data is essential, but a simple statistical package with fundamental metrics would be invaluable. A spreadsheet like Excel can provide sufficient computing power for much of the desired analyses.

The Role of Audiometric Data Management in Hearing Loss Prevention: Audiometric Data Management

John Franks, Ph.D.

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National Institute for Occupational Safety and Health
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In support of the Mine Safety and Health Administration's development of noise control and hearing loss prevention regulations, NIOSH reviewed audiograms for coal miners and metal/nonmetal miners. NIOSH had also been reviewing the 22 databases that were collected under contract for NIOSH in support of the revision of the NIOSH Noise criteria document (these are often referred to as the ANSI databases). The initial databases included more than 22,000 audiograms for coal miners, 40,000 for metal/nonmetal miners, and 158,000 audiograms from the ANSI databases. These databases were longitudinal containing as few as two audiograms and as many as 22 audiograms per person.

Initial review of the audiograms revealed many problems. Audiograms for some persons were inconsistent from year to year. In other cases it was clear that the audiometric thresholds at 500 and 1000 Hz were elevated due to background noise levels in the test environment. There were occurrences of inter-ear differences at the limits of inter-aural attenuation. In other cases, differences in adjacent frequency thresholds were very large. All of these occurrences were very likely due to error in the administration of the audiogram or the recording of thresholds.

In order to remove the suspect data, it was necessary to review the record of each person in the database. Problem audiograms could be marked for deletion, and if a person had only one remaining audiogram, the person's entire record could be removed. A team of five audiologists took on this task for the ANSI databases and later for the audiograms from the coal miners.

Computer programs were written to identify audiograms with threshold shifts of 15 decibels (dB) or greater for the frequencies 500 through 6000 Hz. Additional programs identified audiograms with

larger inter-aural differences of more than 25 dB at 500 Hz and more than 40 dB at 1000 through 6000 Hz—the lower limits of inter-aural attenuation. A further program screened for audiograms with low-frequency thresholds such that thresholds at 500 Hz were greater than those at 1000 Hz by at least 15 dB, and thresholds at 1000 Hz were greater than those at 2000 Hz by at least 10 dB, while the thresholds at 2000 Hz were lower than 15 dB HTL (re ANSI S3.6-1996).

The team of audiologists reviewed the results of each screening and identified those that were to be removed. The decision was also made as to whether to remove a person from the database. While each audiologist could review more than 200 audiograms per hour, the task was fatiguing. Those records remaining after the first screen were submitted to the second screen and those remaining after review of the second screen were submitted for the third. In this way, each successive screen evaluated smaller databases.

Notes were made for each decision to remove a record or all of the records for a person. When the audiograms were reviewed for the metal/nonmetal miners, the task was expedited by an expert system computer program based on the rules for deletion developed by the team of audiologists when they reviewed the other databases. In order to verify that the expert system performed according to the rules and the rules were sufficient, one audiologist's review of 1000 audiograms from the database was compared to the output of the expert system.

The expert system displays all of the audiograms in a database, person by person. Audiograms are flagged for deletion with the reason for the deletion. A reviewer can opt to override the deletion flag and retain the audiogram in the database. The system writes to files containing only the audiograms not

marked for deletion or to files containing all of the data with the deletions annotated.

The present system consists of three programs. Audfilt.exe opens a database file and processes all of the audiograms. Review.exe shows the results of the analysis, person by person. Revout.exe provides the output files for further analysis by other software that may be written in SAS or some other statistical programming language.

The NIOSH expert system evaluates the data for each person in the database, screening for unconfirmed threshold shifts, unsupported baseline audiograms, evidence of too much background noise in the test room, larger inter-aural differences in hearing thresholds, and large adjacent-frequency differences.

There are two applications for this expert system. First, it may be used to screen data that are imported into a database, whether the purpose of the database is to support statistical analysis or to serve as the foundation for a continuing program. Secondly, it identifies persons with problem audiograms so that

they may be followed up. In this case, it may be possible to correct the audiograms if the source of the error is identified.

Draft ANSI standard S12.13, Method for Determining the Effectiveness of Hearing Conservation Programs, performs a statistical analysis of audiometric data, calculating the percent of audiograms with improvement of more than 15 dB and those with thresholds that are worse by 15 dB. It does this for sequential audiograms rather than making comparisons to the baseline audiograms. The standard has criteria for programs that are acceptable, marginal, or unacceptable. Without exception, those audiometric databases that have been filtered by the expert system meet the ANSI S12.13 acceptable definitions.

When HearSaf 2000 is released, it will include elements from the expert system so that each audiogram is screened as it is entered. The system will also evaluate any databases imported, such as from previous computer programs. It is also anticipated that a stand-alone version of the expert system will be available later in 2000.

Audiometric Data Collection and Management

Lt. Col. Theresa Schulz, Ph.D.

United States Air Force

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I am going to discuss the uses of audiometric data and focus on the collection of accurate data. While accuracy is important, hearing conservation audiograms will never be a clinically perfect data set. It is important that the data in hand be used to the maximum benefit of the worker and the company, as waiting for the “perfect” data set means that the useful data currently being collected may be ignored when it has many viable uses in whatever the current condition may be.

There are alternate ways to evaluate hearing conservation programs, including metrics such as standard threshold shift (STS), rates of retest, and comparing subsets within the data. For example, large databases may contain locations or installations where problems occur at a relatively high rate. These outliers can be identified by looking at the data parceled into subsets.

I am now going to discuss using the database to support policy decisions. For example, consider a situation where discussion concerning which exchange rate (3 decibels (dB) versus 4 dB) is most protective was facilitated by analysis of the hearing conservation database. The data indicated that the appropriate exchange rate was level dependent, with

3 dB probably more protective in lower intensities and 4 dB in the higher intensities. The database was also used to determine policy on referral criteria, or hearing thresholds/changes that merit attention by a hearing or medical specialist.

Now I am going to describe a retrospective study where six cases of acoustic neuroma (a type of brain cancer) were discovered that could have been identified in the hearing conservation audiometric process. Database analysis indicated that these cases would have been flagged if criteria in addition to compliance algorithms were used in the hearing conservation program. In this analysis, the study determined hearing threshold criteria that would identify the potential neuromas without the unnecessary concerns entailed with significant false positives. The study determined that the most appropriate criteria for this analysis was asymmetry (difference between ears) of 25 dB or greater at two frequencies.

At present, I am using the hearing conservation audiometric data to educate workers and managers. Use your data to manage the hearing conservation program rather than just parking the data and forgetting about it.

Breakout Session III: Hearing Protection Issues

The Performance of Hearing Protection Devices

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Introduction

Of the many methods for measuring the attenuation of hearing protection devices (HPDs), the protocol for determining real-ear attenuation threshold (REAT) is considered the gold standard for measuring the attenuation of HPDs as worn by a group of test subjects. According to the current EPA regulation for measuring HPD attenuation, the testing is conducted according to a 25-year-old standard published by the American National Standards Institute (ANSI S3.19-1974). By this procedure, the subject is essentially treated as a test fixture, sitting motionless while the experimenter carefully and optimally fits the HPD. Ten subjects are used for the study, which is conducted in a sound-treated room. If the goal is to estimate protection that can be achieved in practice, the test is not a suitable model; however, it does tell you the amount of protection those 10 subjects obtained for the way the product was fitted under the conditions during the test. The question is, does this apply at all to an employee or a group of employees? The answer is no, it does not.

Noise Reduction Rating (NRR)

Prior to 1979, attenuation data for hearing protection devices were commonly available from manufacturers but only in the form of octave-band values. In fact, in most instances hearing protection device attenuation values were simply ignored because of the difficulty of acquiring octave-band workplace noise measurements with the instrumentation of that era, combined with the difficulty in the pre-calculator and pre-computer age of performing multiple tabular computations.

The advent of the Noise Reduction Rating (NRR) and the accuracy and simplicity that it seemed to provide substantially changed the picture, and much attention was then focused on hearing protection device attenuation values. In many instances, either purchasing specifications or hearing conservation program policies were based on the NRR. Use of the NRR in the 1980s was increased when OSHA included it as the preferred method for assessing hearing protection device adequacy for compliance with the Hearing Conservation Amendment. Often additional key parameters of performance such as comfort, compatibility, communication needs, and hearing ability were neglected or overlooked in favor of choosing the hearing protection device with the highest possible NRR. This led to wearer dissatisfaction and consequent misuse or non-use of hearing protection, resulting in inadequate protection from noise or none at all. At the other extreme, correct use of products with too much noise reduction can create communication and safety problems, especially for workers with preexisting hearing losses.

The problem with the NRR is not the computational procedure itself, but rather the optimum-fit laboratory data from which it is computed. Another factor to consider, which arises from test variability, is that differences in the NRR of less than 3 decibel (dB) have no practical importance when buying hearing protection devices.

Available data suggest that 90 percent of noisy industries have TWAs of less than 95 decibels A-weighted (dBA). Therefore, only 10 dB of noise

reduction is needed in better than 90 percent of noisy industries.

The accurate estimate of the attenuation that individuals wearing hearing protection devices receive under conditions of actual use (“real world”) has been the subject of much discussion. Today there are at least 22 studies in greater than 90 industries in 7 countries providing measurements of real-world attenuation. Almost 3000 noise exposed workers participated in real-ear attenuation at threshold measurements for earplugs and earmuffs. When compared, the field estimate data are much lower than the laboratory data. Also, in addition to poorly predicting the absolute values of performance, the data do not give a good measurement of the relative performance of HPDs either. The laboratory data suggest that earplug attenuation is typically equivalent to or greater than earmuffs, whereas the field data indicate otherwise. With the exception of the foam earplug, only earmuffs can generally be expected to provide 10 dB or more of real-world protection for 84 percent of the exposed population.

Unfortunately, the ANSI S3.19 data are the only standardized laboratory values that regulators and manufacturers currently make commonly available for labeling and information purposes. As a very rough rule of thumb, cutting the NRR in half will better reflect real-world performance.

Also to be considered is that when hearing protectors are not worn at all times while in the noise, their effective delivered protection is reduced even further.

Methods for Measuring the Real-Ear Attenuation for Hearing Protectors (ANSI S12.6-1997)

Although few companies can implement the time-consuming procedure needed to individually fit-test each wearer to provide the optimum hearing protection, this can be implemented as discussed in the next paper. However, a better laboratory-based approach does exist, that provides hearing protection devices with the right amount of hearing protection, as discussed below.

Methods for Measuring the Real-Ear Attenuation for Hearing Protectors (S12.6- 1997) is a new standard

developed by ANSI to help resolve the problem of predicting attenuation for groups of real-world users. It consists of two procedures, Method A and Method B. Method A is similar to prior test methods. Method B, Subject Fit, is new. It provides data that approximate the protection that can be attained by groups of informed users in workplaces with representative well-managed and well-supervised occupational hearing conservation programs.

Method B is helpful since leaders in the field have pointed out for over a decade that labeled NRRs computed from existing data, as specified by the Environmental Protection Agency (EPA), overestimate workplace protection for groups of users by as much as 25 dB, depending upon the hearing protector. The keys to Method B are the subjects and how the experimenter works with them. Unlike the EPA-specified procedure in which the subjects behave as test fixtures while the experimenter optimally fits the product (often with earplugs in an unrealistic and uncomfortable manner), in Method B, the subjects, although trained and experienced in audiometric test taking, are naive with respect to the use of hearing protection and are simply told to fit the device to the best of their ability. They work from the manufacturer’s printed instructions with no assistance whatsoever from the experimenter.

Unfortunately, the regulation that specifies the labeling of hearing protectors not only does not recognize the new 1997 standard but still requires testing by the government’s interpretation of a 25-year-old S3.19 standard that is no longer supported by ANSI. The EPA’s Noise Office closed in the 1980s, and nothing is being done to revise the existing rule. The current hearing protector NRRs based on testing to the old ANSI standard are of even less accuracy and value than the original much maligned EPA fuel-economy ratings. The procedures behind the fuel-economy ratings were improved, but those behind the hearing protector ratings have not been.

Method B still overestimates field performance, but results are closer to field values. A new number rating computed from the new Method B data, called the NRR(SF), which stands for NRR Subject Fit, has been suggested by the National Hearing Conservation Association (NHCA) Task Force on Hearing Protector

Effectiveness. Some manufacturers make these data available.

Maintaining an effective hearing conservation program requires work. A lot of people complain that they cannot hear when they wear hearing protection so they don't want to wear it. In terms of noise reduction, which is often accomplished after-the-fact with a noise enclosure, and its effect on sound quality, there is little difference between putting the box (i.e. noise enclosure) on the employee's head (earmuffs) or putting the box around the machine. Furthermore, other types of engineering controls often require skill and attention, and achievement of even a few decibels can be difficult. Thus, hearing protection devices can be, and often are, required as

an effective adjunct to engineering controls in the majority of industrial noise environments.

For additional information, see the following references. Reference number two is the original article on which much of the information in this précis is based.

Berger, E. H. (1993a). "EARLog #20 - The Naked Truth About NRRs," E A R, Indianapolis, IN.

Berger, E. H. (1999b). "EARLog #21 - Hearing Protector Testing - Let's Get Real," E A R, Indianapolis, IN.

Berger, E. H., and Royster, L. H. (1996). "In Search of Meaningful Measures of Hearing Protector Effectiveness," Spectrum Suppl. 1, 13(1), p. 29.

Insert-Type Hearing Protector Attenuation Measurements on End-Users in the Steel Industry

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Evaluation of Insert-Type Hearing Protector Attenuation in the Field

A field measurement system is currently available for the evaluation of attenuation provided by insert-type hearing protectors on end-users. This system essentially replicates the laboratory test procedure using headphones to deliver the test stimulus.

Because the attenuation is measured after the end-users have donned the hearing protection devices (HPDs), the measurement represents achievable field attenuation. The test procedure involves measuring the hearing thresholds of HPD end-users with and without hearing protectors in place. Essentially, the attenuation provided by the protector is equal to the difference between these threshold measurements.

The headphones in this system are designed for high output and unobtrusive wearing. They are relatively large to prevent affecting attenuation by physically contacting the protector. The headphones must be capable of generating high output levels as it is necessary to measure hearing thresholds of individuals with significant hearing loss who are wearing high attenuation earplugs. In addition to the headphones, the measurement system utilizes custom designed software, a PC sound card and a computer controlled attenuator.

To determine the validity of this system, results were compared with laboratory tests using several different types of earplugs. Both the laboratory test (ANSI S3.19-1974) and the field measurement system were performed on 10 male and 10 female subjects. The subjects donned the earplugs and the fitting was not modified between the two tests.

Comparison of the field measurement system data and the ANSI S3.19-1974 test results indicates high correlation at all test frequencies: 125, 250, 500, 1000, 2000, 3150, 4000, 6300, and 8000 Hz. At 2000 we see the poorest correlation of any of nine frequencies, probably due to the relatively low bone

conduction thresholds. Regression coefficients are incorporated in the field measurement system software, allowing the user to compare field measurement data to the laboratory data labeled on the hearing protector package.

The field measurement system has been shown to be practical to use in an industrial environment. A complete five frequency test can be performed in about seven to ten minutes. A screening test of one or two frequencies can be performed in only a few minutes, and these results may be satisfactory for most purposes. ANSI S12/WG11 will standardize field measurement systems in the future.

Steel Industry Study

In the summer of 1998, the attenuation provided by insert-type hearing protectors was evaluated on 389 steelworkers during their annual audiometric test session. The HPD field measurement procedure was performed after the employees had watched a video on proper hearing protector fitting techniques. At this industry, workers were allowed to select hearing protection devices from a choice of several types without assistance. Most individuals indicated that they had selected plugs based on comfort. Over half of the employees selected a specific triple flanged reusable plug. The second most popular device was a specific urethane foam plug (85 wearers).

The field measurement system calculates a Personal Attenuation Rating (PAR), which is simply an A-weighted reduction value. The distribution of PARs across all workers and all hearing protection devices was bimodal. In other words, most workers either received relatively high attenuation or relatively low attenuation.

Examination of the distribution of PARs according to plug type revealed the cause of the overall bimodal distribution. More than half of the urethane foam plug wearers received greater than 20 decibels (dB) of attenuation, and more than half of the silicone reusable plug wearers received less than 10 dB of attenuation. It was apparent that the silicone plugs selected primarily for comfort were too small for many of the workers.

The field attenuation measurements at 250 Hz were most indicative of the quality of hearing protector device fit. The relatively poor fitting by many reusable plug wearers resulted in almost no attenuation provided at the lower test frequencies. In the higher frequencies, the foam plug provided attenuation of 20 dB or more for almost all wearers. The reusable plug wearers received highly variable protection at 4000 Hz, with 22 percent receiving less than 10 dB of protection.

One hundred and five of the test subjects who received less than 8 dB of overall protection were retested in December of 1998. These users were retested under the same conditions, reinstructed on proper fitting technique, and then refitted with one of several styles of sized insert-type protectors. The retest indicated improvement in the attenuation provided by the plugs: 50 percent of the subjects received greater than 20 dB of attenuation. The average improvement across subjects was 14 dB.

Summary

Measuring the attenuation provided by insert-type hearing protectors has been shown to be practical for use in industry as a supplement to the annual audiometric evaluation. The data gathered in these evaluations are valuable for both the industry and the end-user. The end-user receives more effective protection, and the industry is provided with documentation on effective hearing protector training and fitting. This procedure is a key component in the personalization of the hearing conservation program.

Attenuation and Active Noise Reduction

The last part of the session included a discussion on flat and moderate attenuation and active noise reduction (ANR).

Flat and moderate attenuation earplugs and earmuffs provide the benefits of improved user acceptance, avoidance of overprotection, and enhanced communication and signal detection. ANR devices use reverse-phase acoustical principles and electronics to develop “anti-noise,” or signals exactly out of phase from the source, resulting in “cancellation” of the offending signal. The ANR protector was found to be excellent for canceling low frequency sounds but was only effective in limited applications. Examples include some military environments where noise sources exceed 115 decibels, A-weighted (dBA), and the main frequencies were below 500 Hz. ANR is not useful for most nonmilitary occupational settings.

Breakout Session IV: Employee Training and Motivation for Effective Hearing Loss Prevention

Preventing Noise-Induced Hearing Loss in Construction Workers: A Video-Based Training Program

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Utilizing a grant from the National Institute for Occupational Safety and Health, Dr. Lusk and her research team at the University of Michigan developed a training program incorporating video instruction, pamphlets, and guided practice in fitting hearing protectors. This training program was demonstrated through a workshop for the benefit of attendees at the Best Practices in Hearing Loss Prevention Conference held in Detroit.

The purpose of developing the training program was to increase the use of hearing protectors among trade groups in the construction industry. The program was initially evaluated with carpenters, operating engineers, and plumber/pipefitters. Phase one of the study involved surveying over 350 construction workers to identify factors associated with use or disuse of hearing protectors in appropriate noisy construction settings. Phase two of the study involved using the Health Promotion Model (Pender, 1987) as a framework to design and pilot test a draft training program. In phase three, the final version of the program was evaluated with three groups of construction workers. The training program package is currently available nationwide from the American Industrial Hygiene Association.

The training program, as demonstrated at the conference, consists of videotaped information on hearing health and hearing loss prevention presented by actors portraying an occupational health nurse and

construction workers. Sample hearing protectors are included in the training kit and are designed to be used during a practice session guided by trainers. Mastery skill training in the proper selection, fit, and use of a variety of hearing protection devices is a critical part of the training program. Participants in the training learn hands-on “tips and tricks” that will help ensure that they use these devices effectively. An informational brochure is also provided to the participants for personal reference.

Significant Findings from Dr. Lusk’s Program Evaluation Study Include:

- The training program led to a significant 13 percent increase in use of hearing protectors by plumbers/pipefitters; however, these workers’ use of hearing protection overall was still inadequate to prevent noise-induced hearing loss. Self-reported mean use of hearing protectors ranged from 18 percent to only 50 percent of the time spent in hazardous noise.
- The program did not lead to a significant change in hearing protector use among carpenters and operating engineers. Preliminary data suggest that work organization factors and the “work culture” associated with these two trades may present significant barriers that should be directly addressed in delivering this training to these groups. Additional research is planned.

Why Training Needs Change

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In thinking about any training including hearing loss prevention, three main goals come to mind:

- Imparting knowledge *that participants will remember*
- Building skills *that participants will feel competent to use*
- Instilling motivation in participants *so that they will champion safe work practices*

We know that training is not a one-shot endeavor. Training approaches for any subject need to constantly evolve because our work environments are not static. For example, as occupational safety and health educators, we expect to find some yearly changes in our audience, changes in the work environment, and changes in recommendations or regulations. Additionally, an evaluation of your training for effectiveness may indicate deficiencies suggesting a need to change your approach. Finally, we live in a time of constantly changing technology, and you may wish to try new media or alternate methods of delivering training to workers.

Arguably, one of the most critical of the elements noted above depends on the ability of the trainer to understand the audience and respond to changes in that audience over time.

A stable, homogeneous workforce will move through predictable “stages” reflecting varying degrees of receptivity to health and safety messages. In contrast, a diverse workforce with high turnover challenges the trainer to reassess the audience and tailor his or her messages each time training is provided. “Stages of change” models can be useful tools that aid the trainer in preparing and delivering health and safety training.

Stage models differ from many commonly known health behavior models (e.g. Health Belief or Health Promotion models, Theory of Reasoned Action) in significant ways. While the health behavior models stress predictability of behavior based on interactions of attitudes, beliefs, and situational barriers, stage

models view the adoption of new behaviors as a series of events linked to an individual’s spiraling progress toward understanding and personally choosing to adopt the new behavior. A strength of “stages of change” models is that they permit the detection of movement toward a desired behavior change well before people actually demonstrate the desired change. A wealth of research now suggests that people at different “stages” in the change process behave in distinctly measurable ways, and thus, the training interventions needed differ at each stage.

There are several “stages of change” theories, but one that has received extensive testing and evaluation in a number of settings is DiClemente & Prochaska’s model (for ref. See: Prochaska JO, DiClemente CC, & Norcross JC (1992). In Search of How People Change: Applications to Addictive Behaviors, *American Psychologist*, 47:1102-1114). This theory proposes five stages:

- **Precontemplative**—People in this stage do not recognize the issue or feel any need to change their behavior.
- **Contemplative**—People in this stage are aware of the issue and are seriously thinking about changing their behavior.
- **Preparation**—These individuals are making a personal commitment to change and taking the first steps to prepare for behavior change.
- **Action**—People in this stage have successfully adopted the desired behavior change according to their plan...and are in the first six months of action.
- **Maintenance**—These individuals continue the successful behavior change from six months through an indefinite time period.

The theory notes that this process is not perfectly linear; most individuals relapse and recycle through one or more stages as they attempt a permanent behavior change. Perhaps the aspect of the theory most helpful to educators and trainers relates to the factors and processes that help individuals progress through each stage. For example, trainers and

educators can help people move from *precontemplation* to *contemplation* by raising consciousness about the issue at hand. This can be accomplished by providing information about an issue and by raising the audiences' perception of their personal risk. Often this is done by describing the "new" health threat in terms of comparisons with activities widely regarded by society as being risky. This is not always easily accomplished. Risk perception literature has taught us that to be seen as credible, only risks with similar profiles should be compared in health messages. This means that to raise consciousness about occupational hearing loss it should be compared to a well-known risk that is similar in terms of factors such as dread of getting the illness, degree of personal control possible in avoiding the illness or curing it if acquired, catastrophic potential from the illness, and novelty of hearing loss. One of the great frustrations among hearing conservationists for decades has been the inability to create a sense of dread, urgency, and concern about occupational hearing loss. Despite this failure, one may encourage *precontemplators* to move toward the *contemplation* stage by getting their attention, providing factual information about the issue, and creating an environment that helps people choose healthy behaviors.

What about the *contemplators*? These individuals are aware of the problem, so simply providing more "facts" is unlikely to spur them to action. They are thinking about changing their behavior, but are unsure how to go about it. For people in the contemplation stage, research suggests that an individual must actively choose from a repertoire of possible behaviors relevant to the issue and must develop and commit to a course of action. In essence, training must help people in this stage choose options that move them from contemplation to preparation. One way to do this is to assess the individual's decision making perspective and attempt to help them consider the costs, benefits, and probabilities of future handicaps associated with preventing or not preventing hearing loss.

A particular difficulty facing hearing health educators is the time/line associated with noise-induced hearing loss. Quite simply, many people initially consider the burden of protecting their hearing disproportionate to any future consequences of poor

hearing during their retirement years. The challenge at this stage is to convince workers to look at the ramifications of noise-induced hearing loss from a new perspective.

After adequate contemplation, people ideally move into a stage of preparing for behavior change. Individuals in the *preparation* stage increasingly recognize and appreciate the "pro" arguments favoring the contemplated behavior change. They begin taking steps that will facilitate their ability to adopt new behavior. For example, they may purchase hearing protectors, participate in a sound survey of their workplace, or schedule an appointment for a hearing test.

Preparers are moved to *action* when they are able to set reasonable goals for themselves. Trainers and educators can assist people at this stage by helping workers assess goals and plans for feasibility and by directing efforts at identifying and overcoming any barriers that hinder adoption of healthy behaviors. Workers who are encouraged to make public pledges, particularly to peers, to engage in the new behaviors are often most successful at moving into action. People in the action stage "intend" to maintain their new healthy behaviors and benefit from encouragement of each small step taken along the way.

If the environment remains supportive and barriers continue to be addressed as they crop up, the new behaviors can be *maintained* indefinitely. Individuals in the maintenance stage are strong champions of healthy behavior and publicly identify themselves as proponents of the "new" safe work practices. Maintainers will likely face occasional "relapse," which is often precipitated by a breakdown in the environmental support structure. Trainers and educators can prepare their audiences for this possibility and assure them that these instances are best managed from a constructive, problem solving perspective. For example, a supervisor's forgetful delay in refilling the hearing protector supply box could result in workers being unprotected in noise during an entire work shift. Similarly, it is not uncommon to find that workers may delay reinstalling a noise control device on a piece of machinery following maintenance. In both cases, focusing on a plan that will minimize these

conditions in the future will be a more constructive and rewarding approach than simply confronting the “relapsing” individuals in an adversarial manner. Educating people that “relapse” usually happens when people are frustrated by barriers or in a hurry may help. Stable behavior change takes practice and patience.

Finally, educators and trainers in the health and safety arena often need to be reminded that culture also shapes worksite behavior, values, and overall receptivity to new behaviors. Appreciating the diversity within a work group is just as important as recognizing diversity between work groups. Carpenters, miners, assembly line workers, and farmers all experience noise on the job, but your hearing conservation messages should be tailored to the characteristics associated with each work sector and your assessment of the stage of readiness each audience exhibits toward adopting change. Evaluate your training program on an ongoing basis for relevance to your audience and effectiveness at producing the desired effects. Potential questions to ask include, “Do you have evidence that:”

- Your audience pays attention and learns from the training?
- The audience can recall and apply the information appropriately by displaying needed skills (such as how to select and fit hearing protection)?

- The audience responds to your training by progressing toward adopting safe work behaviors (retrofit engineering controls, increase wearing time of hearing protectors, etc.)?
- Your training actively addresses the barriers and issues perceived by your audience? This requires that you *ask!*

This is an exciting time for educators and trainers. No longer is yearly hearing conservation training limited to the same boring video year after year. Technological advancements allow the use of camcorders, digital cameras, and computer graphics to personalize training to each work environment or even to each team of workers. There are many jazzy new videos and CD-ROM products, interactive “real-life” problem solving scenarios, and guidance available on the Web for making “home-grown” training materials involving your workforce. Noted below are just a few of the many Web sites offering health and safety education and training and/or hearing loss prevention information.

www.cdc.gov/niosh/noise.html

www.nih.gov/nided

www.osha.gov

www.aiha.org

www.caohc.org

www.lhh.org

www.hearingconservation.org

www.nsc.org

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For Information on Other
Occupational Safety and Health Concerns

Call NIOSH at:
1-800-35-NIOSH
(1-800-356-4674)

or visit the NIOSH Homepage at:
<http://www.cdc.gov/niosh/homepage.html>



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