

## **Paparella: Volume II: Otology and Neuro-Otology**

### **Section 2: Audiology**

#### **Chapter 12: The Otolaryngologist and the Occupational Safety and Health Act**

**Philip M. Sprinkle, Conrad Lundeen**

The problem of occupational impairment of hearing presents both a challenge and an opportunity to otolaryngology. More workers are exposed to potentially damaging levels of noise than to any other significant occupational hazard (Olishifski and Harford, 1975). The Department of Labor estimates that, at present, noise in the workplace presents a significant danger to the hearing health of 5.2 million workers in USA industry alone. Ten million industrial employees may already have hearing loss caused by excessive exposure to noise.

Over the next decade, several billion dollars will be paid to compensate workers for hearing losses caused by job-related noise. The human cost is more difficult to calculate. Hearing loss caused by chronic exposure to hazardous noise is particularly threatening because it develops so insidiously that the victim may be unaware of any problem until everyday communication is affected. Since the impairment results from permanent damage to cochlear structures, it cannot be reversed by medical treatment.

Noise-induced hearing loss can, however, be prevented. Federally mandated programs for hearing conservation are designed to protect workers exposed to high levels of noise from suffering "material hearing impairment". These programs hold the promise of preventive medicine at its best, and the otolaryngologist should be integrally involved in administering them and expanding their effectiveness. For these efforts to be successful, the physician must be familiar with the medicolegal aspects of industrial programs for hearing conservation.

Otolaryngologists frequently provide executive agencies, legislative committees, compensation boards, and other governmental units with scientific data and expert advice concerning the injurious effects of excessive exposure to noise and often serve as expert witnesses when occupational hearing loss results in litigation. The credibility of the physician's data, advice, and testimony will be judged not only by its merit but also by how well he or she knows and understands the pertinent regulations. All too often, medical interpretations become distorted when translated into legal facts. This is particularly true when medical testimony is used to adjudicate compensation claims.

No diagnostic test can differentiate noise-induced hearing impairment from cochlear damage caused by other factors. When hearing impairment results from multiple causes, no test can quantify the proportion of loss attributable to noise exposure. Instead, data from the case history, noise exposure measurements, physical findings, and the results of audiometric and other tests must all be evaluated in order to determine whether a particular hearing loss is totally or

partially noise-induced. The conclusions drawn from this evaluative information must be clear and specific. Otherwise, unexpected consequences may result from the otolaryngologist's testimony.

For instance, suppose a retiring worker with sensorineural hearing loss had been exposed to hazardous levels of noise for a total of 1 hour during the course of 40 years in the workplace. The physician may testify that the noise exposure is clinically insignificant and unrelated to the major cause of the hearing loss. In many states, however, the admission that noise levels during the isolated exposure had even the slightest potential for damaging hearing is enough for the court to conclude that exposure to noise aggravated a pre-existing condition, and that the worker is entitled to compensation for the entire hearing impairment.

Since exposure to noise is second only to presbycusis as the most common cause of hearing impairment (Dobie, 1982), the effective management of many patients seen in general otolaryngologic practice also depends, at least in part, on the physician's familiarity with the noise exposure restrictions and hearing conservation provisions of government statutes. Thus, for medical, professional, and ethical reasons, no otolaryngologist can afford to ignore government noise control regulations.

This chapter reviews factors involved in occupational hearing loss, with special emphasis on the provisions of the Occupational Safety and Health Act that apply most directly to the otolaryngologist.

### **Federal Noise Regulations**

Any private industry that does more than \$10,000 worth of annual business with the federal government must comply with the provisions of the Walsh-Healey Public Contracts Act of 1936 that protect employees from occupational injuries and diseases. Under the authority of this Act, the US Department of Labor (DOL) issued regulations in 1969 that required industries to use "feasible administrative or engineering controls" to reduce workers' exposure to noise to permissible limits set by the DOL. If hazardous levels of noise persisted, affected employees were to be included in a program for hearing conservation and provided with personal protective equipment.

These landmark regulations have gradually been strengthened and expanded to cover larger segments of the USA work force. The Federal Coal Mine Health and Safety Act of 1969, administered by the Department of Interior's Mining Enforcement and Safety Administration (now the Mining Safety and Health Administration (MSHA)), incorporated the Walsh-Healey noise control standards along with other coal-mining, safety and health measures. In 1970, the Occupational Safety and Health Act (OSHAct) authorized the Secretary of Labor to set mandatory occupational safety and health rules for all businesses affecting interstate commerce. The OSHAct adopted the safety and health provisions of the Walsh-Healey Act as interim regulations until new ones could be promulgated.

The OSHAct of 1970 also created two new agencies. In the DOL, the Occupational Safety and Health Administration (OSHA) was formed to administer and enforce the OSHAct. The National Institute for Occupational Safety and Health (NIOSH) was added to the National Institutes of Health in the Department of Health, Education and Welfare (now Health and Human Services) and charged with conducting research, developing identification criteria for occupational hazards, and recommending safety standards to the DOL.

In 1972, NIOSH presented new noise control standards to the Labor Department that were designed to replace the interim Walsh-Healey regulations of the 1970 OSHAct. At the same time, the Noise Control Act of 1972 authorized the Environmental Protection Agency (EPA) to coordinate and review the activities of all federal agencies related to noise research and control. The EPA, along with many labor representatives and other concerned professionals, challenged the newly proposed regulations as being too lax.

After almost a decade of discussions, research, and hearings, in January, 1981, OSHA promulgated an amendment with detailed requirements for hearing conservation programs. A new storm of controversy, punctuated by lawsuits, forced the effective date of the amendment to be delayed several times. On August 21, 1981, major portions of the new OSHA regulations went into effect. However, an administrative stay on the more detailed provisions of the Hearing Conservation Amendment was continued, and the record was reopened for additional comment.

The "Final Rule" specifying requirements for hearing conservation programs was promulgated in 1983, but the regulations were overturned by a successful legal challenge. Subsequently, on September 23, 1985, the US Court of Appeals upheld the Hearing Conservation Amendment Final Rule.

Although court appeals are still possible, the 1981 and 1983 regulations of occupational noise exposure and hearing conservation, which are discussed in the following sections of this chapter, are now in full force, and their continued enforcement seems likely. These regulations cover all employees in the private sector except those engaged in the oil and gas well drilling and servicing industry, in construction, and in agriculture. Federal employees and military personnel are protected by noise regulations that are the same as or even more stringent than those imposed by the OSHAct.

### **Identification of Hazardous Noise Environments**

The risk of acquiring noise-induced hearing loss depends mainly on the intensity of the noise and the duration of the worker's exposure to the noise. In order to differentiate between hazardous and nonhazardous environments, the OSHAct sets permissible exposure levels for noise, which form the basis for all other noise regulations. An introduction to noise measurement techniques is required to make these standards understandable.

Most commonly, noise intensity is measured in decibel (dBA), units using a sound-level meter with an "A" weighted frequency response. Sound energy in the frequency region of 1000

to 5000 Hz, which is most injurious to hearing, is emphasized when noise levels are measured in *dBA*. Since these measures are easily made and provide a good estimate of how hazardous a particular noise is, all federal agencies use *dBA* to evaluate occupational and environmental noise levels.

Investigations of the potential for a specific noise level to damage hearing have usually been made when the noise is at a steady, continuous level during the entire work shift, as it is in many industrial manufacturing operations and power plants. One-fourth to one-third of the work force is exposed to noise levels above 85 *dBA*, and some industrial noise levels reach 115 *dBA* (Bolt, Beranek and Newman Inc, 1981).

Since the dawn of the industrial revolution, the creation of new safety and health hazards has been part of the price of progress. Measures that reduce or prevent occupational hazards are practical only up to the point where the cost for workers protection becomes so high that it prohibits the activity that created the problem in the first place. At this point, the activity's benefit to society must be weighed against the residual risk to individual workers.

The development of our highway system exemplifies this dilemma. Workers employed in the excavation and paving of roads are subjected to risks from accidental injury and from exposure to hazardous substances and conditions. In order to eliminate these risks, however, automotive transportation would have to be abandoned entirely - a cost which society is unwilling to pay.

The noise exposure limits imposed on US industry also represent a compromise between protection and practicality. Some researchers believe that 8-hour workday exposures to noise levels as low as 55 *dBA* can cause significant hearing loss in some workers (Kryter, 1973). Since 55 *dBA* roughly corresponds to the level of a quiet conversation, it is impossible to protect all individuals from sustaining any noise-induced hearing loss.

For any practical noise exposure limit, most workers will sustain some high-frequency hearing loss by the end of their working lifetimes, and others will have a handicapping degree of hearing impairment. A common rule of thumb is that when workers are exposed to continuous noise 8 hours a day for 10 to 20 years, the probability of developing hearing loss is zero when noise levels are below 80 *dBA*. The probability climbs to about 50 per cent when levels reach 95 *dBA*. At 105 *dBA*, nearly all workers will suffer noise-induced hearing impairment (Ward, 1968).

The OSHA Act specifies that 90 *dBA* is the maximum *permissible exposure level* (PEL) for an 8-hour workday. PELs for a variety of time periods are presented in Table 1. As the table shows, noise exposure standards incorporate the so-called *5-dB rule* of time-intensity trading: that is, if the worker's duration of noise exposure is cut in half, then noise levels can be raised 5 *dB* before the permissible limit is reached.

In order to quantify the extent of a worker's exposure for a given noise level, their *noise dose* can be determined by calculating the percentage of the exposure time limit that was actually consumed by the duration of the individual's exposure. For instance, the noise dose of a worker subjected to 95 dBA for 4 continuous hours would be 100 per cent, since this is the maximum duration allowed by the regulatory limits shown in Table 1. Computations of noise dose for other exposure levels or durations follow the 5-dB rule or doubling the duration of noise exposure will increase the noise dose twofold. Thus, exposures to 100 dBA for 4 hours or to 95 dBA for 8 hours would yield a 200 per cent noise dose.

**Table 1. Permissible Exposure Limits (PELs) to Continuous Noise**

Noise Level (dBA)	Permitted Daily Exposures (hours-minutes)
90	8-0
92	6-0
95	4-0
97	3-0
100	2-0
102	1-30
105	1-0
110	0-30
112	0-15

Personal dosimeters have long been used to measure accumulated radiation exposure. Now, *noise dosimeters* have been developed that can be attached to individual workers to measure their personal noise dose. OSHA routinely uses personal dosimeters to evaluate compliance with noise regulations. Noise doses of 100 per cent or less are considered acceptable, whereas higher doses are assumed to present a progressively increasing hazard to hearing.

In industry, workers are usually subjected to different noise levels during their work shift. Whenever exposure is composed of two or more periods of noise at different levels, their combined effect must be evaluated. A survey of variable or intermittent noise levels can be accomplished using a sound-level meter and stop-watch. However, it is more convenient to use a dosimeter, which accumulates and integrates exposure throughout the workday.

The concept of *time-weighted average* (TWA) can be used to convert noise dose measures to a dBA quantity that is equivalent to steady-state PELs, as shown in Table 1. TWA is the level at which a constant noise would have to be maintained for an 8-hour period in order to cause the same noise dose that was measured in a situation with fluctuating noise levels. For instance, a measured noise dose of 100 per cent would be equivalent to an 8-hour TWA sound level of 90 dBA; a 200 per cent dose corresponds to an 8-hour TWA of 95 dBA.

## **Noise Control**

The most important goal of all industrial hearing conservation programs is to reduce the level of noise to the point where it no longer poses a threat to hearing. The combined efforts of management, engineering, and medical personnel are required to achieve this goal. Methods of reducing exposure to high noise levels range from purchase of new, quieter machinery to fitting employees with personal protective equipment. This section provides an overview of noise control measures, with special emphasis on the use of hearing protectors, since this approach requires the direct involvement of health care professionals.

### **Engineering and Administrative Controls**

The OSHAct requires the utilization of "feasible" engineering or administrative controls to reduce workers' noise exposure to within the PELs shown in Table 1. Engineering controls employ three basic techniques to actually reduce the noise intensity reaching the worker. First, noise may be attacked at its source by modifying the design or operation of machinery to make it quieter or by adding acoustic mufflers to reduce sound levels. Second, barriers or sound-absorbent materials may be installed to keep high levels of noise from being transmitted throughout the workplace. Last, remote-control systems for noisy operations may be developed, so that the worker can be placed in a protective enclosure.

Administrative controls involve procedures that limit daily exposure to noise by modifying the work schedule. For example, the scheduling of noisy operations may be staggered over different work shifts, or employees may be rotated from noisy to quiet locations to limit each individual's noise dose.

OSHA's determination of the feasibility of engineering and administrative controls is based on cost and technological considerations. Clearly, if controls are technically impossible, other methods of reducing noise hazards must be employed. OSHA has maintained the position that noise controls are economically feasible if the expenditures will not put the firm out of business. In practice, feasibility limits defined in terms of dollars per employee range from around \$3000 to \$30,000 per employee, depending on the particular situation.

### **Personal Hearing Protectors**

Personal hearing protectors are devices that occlude the outer ear in order to attenuate sound. There are three basic types: earplugs, earmuffs, and ear canal caps. Employers must make a variety of suitable protectors available without cost to all employees exposed to TWA noise levels of 85 dBA or greater. When noise levels above 90 dBA TWA persist because other noise control measures are not feasible or have not yet been completed, employers must provide hearing protectors for all exposed employees and ensure that these devices are used correctly at all times. Employees exposed to levels above 85 dBA also are required to wear protectors when periodic audiometric testing indicates that their hearing has deteriorated. In effect, recent enforcement guidelines (OSHA, 1983) exempt companies from instituting engineering and

administrative controls so long as the use of personal hearing protectors is required and noise levels do not exceed 100 dBA TWA. Consequently, the effective utilization of hearing protectors in hearing conservation programs is more important now than ever before, and industrial physicians and audiologists must be familiar with the characteristics and limitations of these devices.

### **Earplugs**

Although custom-molded earplugs are available from most earmold laboratories, preformed and hand-formed earplugs are the types used most frequently in industry. Preformed earplugs come in different styles and sizes, and must be fitted to each individual ear. Hand-formed earplugs, usually made of a compressible plastic foam, are available in a single size that is reshaped to fit the ear canal each time it is inserted. In comparison with other hearing protectors, all types of earplugs are initially cheaper, and easier to carry and clean. Also, they cause less interference with eyeglasses, earrings, hair styles, protective headgear, and work activities in close quarters. On the other hand, individual fitting and special training is required to ensure that earplugs are used correctly. Because earplugs are small and often obscured from view, it is difficult for supervisors to know whether employees are complying with hearing protection requirements, especially at a distance. Over a long period of time, earplugs may irritate the ear canal, or cause normal accumulations of cerumen to become impacted. When infection is present, earplugs cannot be worn.

Fitting for earplugs requires an initial examination of the ear canal to rule out the possibility of infection and to determine the size and shape of the canal so that a proper device may be selected. Many potential problems can result when earplugs, like any other foreign object, are pushed into the ear canal. For these reasons, it is strongly recommended that the dispensing of earplugs be treated as a medical prescription.

### **Earmuffs**

Circumaural protectors, commonly called earmuffs, cover the entire outer portion of the ear with cups or domes and seal against the side of the head with a plastic cushion. This cushion is usually held in place by a spring-loaded suspension assembly attached to a hard-hat or by a headband worn over the head. Earmuffs generally cause minimal problems, can usually be worn with medical supervision when infections or ear canal irritations are present, and provide less variable amounts of attenuation than do earplugs; also, supervisory monitoring of compliance and proper use is considerably easier. However, the devices are relatively bulky and hot, more difficult to maintain and clean than earplugs, and cumbersome to wear with other protective headgear; furthermore, the pressure exerted by the spring-loaded suspension assembly sometimes causes the complaint of headache. Finally, the initially cost of earmuffs is relatively high, which may be viewed as a disadvantage by some employers.

## Ear Canal Caps

Ear canal caps are similar to earmuffs, except that they cover only the external opening of the ear canal rather than the entire ear. In order to create an acoustic seal, the canal caps are held in place by a light headband or other suspension system. Like earmuffs, a single size will fit most adult heads. Ear canal caps are recommended for occasional short-term noise exposure, particularly in situations in which earmuffs are too warm or bulky.

### Attenuation Provided by Hearing Protectors

When personal hearing protectors are used for hearing conservation, employers must document that the attenuation provided is adequate to reduce the exposures of all employees to at least 90 dBA TWA, and to 85 dBA TWA for employees who experienced threshold shifts in the past. Laboratory data indicate that the attenuation provided by hearing protectors is in the range of 5 to 25 dB at low frequencies and 25 to 45 dB at high frequencies. Earplugs generally provide a more variable amount of protection than do earmuffs. However, if they are worn properly, many earplugs yield attenuation values comparable to earmuffs. An additional 5 to 10 dB of attenuation can be obtained by wearing plugs and muffs together. The EPA has developed a single-number indicator of hearing protector performance that can be used to estimate a device's effective noise attenuation in decibels. This value, called the *noise reduction rating* (NRR), must be included on the label of all hearing protectors (EPA, 1979).

Several methods for estimating the noise levels using hearing protectors are acceptable to OSHA. The simplest is to subtract the ear protector's NRR from the measured ambient noise levels. When noise measurements are in dBA, 7 dB must first be subtracted from the NRR to correct for differences between this quantity and dBA. To illustrate, if a worker exposed to levels of 100 dBA TWA wears hearing protectors with an NRR of 27, noise exposure with protection is estimated to be  $100 \text{ dBA} - (27 - 7) = 80 \text{ dBA}$ .

In the workplace, the real amount of attenuation provided by hearing protectors is commonly found to be no more than half the NRR measured by the manufacturer under laboratory conditions. Consequently, it is good practice to "derate" attenuation estimates by 50 per cent. Thus, if a device's  $(\text{NRR} - 7) = 20 \text{ dB}$ , it is prudent to assume that only a 10-dB reduction in exposure to noise is actually achieved when the protector is worn by the average worker.

OSHA's guidelines for evaluating the attenuation offered by personal hearing protectors are currently under review, and estimate that more accurately reflect the amount of protection achieved in "real use" situations may be forthcoming. In the meantime, medical personnel must use their best judgment to ensure that the hearing protectors they recommend are adequate to protect workers from hazardous noise levels with a comfortable margin of safety. However, issuing devices that provide a great deal of attenuation but are uncomfortable or unacceptable to the worker invites noncompliance and is counterproductive. The efficacy of hearing protectors depends more on intelligent fitting practices and careful instruction than on the device itself.



## **Audiometric Testing**

The only way to ensure the effectiveness of a hearing conservation program is to measure employees' hearing sensitivity periodically. For this reason, the OSHAct now requires an audiometric testing program for all employees with average noise exposure levels of 85 dBA or more. This program must include, at no cost to the employee, baseline testing and annual monitoring to identify workers whose hearing is deteriorating. A primary goal of audiometric monitoring is to determine whether hearing loss is being prevented by the employer's hearing conservation program. In addition, periodic hearing tests, when supported by responsible follow-up and otologic referral procedures, represent an important health screening benefit for the employee. An audiometric testing program also provides a unique opportunity to educate workers individually about their hearing and the need to protect it. The full potential of an audiometric testing program cannot be achieved if it is designed only to meet minimum standards required by law. Since OSHA allows substantial leeway in developing testing programs that comply with the regulations outlined in the following selections, we also present supplemental steps to improve employees' hearing health care and to protect employers from unjustified compensation claims.

## **Personnel**

Audiometric testing programs must be directed by a "licensed or certified audiologist, otolaryngologist, or other physician" (Federal Register, 48:9777). This professional is responsible for overseeing the program and the work of technicians, reviewing problem audiograms, and determining when otologic/audiologic referral is necessary. Hearing tests may be performed by professionals or by technicians who are either certified by the Council of Accreditation for Occupational Hearing Conservation (CAOHC) or trained on-the-job. Certified or specially trained technicians are not required, however, when microprocessor audiometry are used to administer audiometric tests. Whoever conducts the actual evaluation is responsible for ensuring that the environment and the equipment and procedures employed are appropriate for measuring accurate hearing thresholds. Audiograms must also be screened to identify threshold shifts or other problems that require further evaluation.

Although OSHA explicitly recognizes the importance of otolaryngology in hearing health care, direct medical participation in industrial hearing conservation programs is not required by the agency's final rule. The prudent employer will recognize that industrial hearing conservation, as it relates to plant safety and employee health care, is a program of preventive medicine designed to protect a vital biological function that demands full medical supervision. In addition, medical participation serves to protect industrial management against compensation claims for hearing losses that are due to causes other than noise exposure. Therefore, otologic examination and medical management are necessary for the success of any hearing conservation program.

## Procedures, Equipment, and Record-Keeping

In order to comply with OSHA standards, all audiograms must include pure-tone air-conduction thresholds measured at 500, 1000, 2000, 3000, 4000, and 6000 Hz in each ear. Since differences in measurement techniques are a major source of threshold variability, and since no standard method is specified by OSHA, the supervising professional must ensure that all audiograms are obtained using a single procedure. A reliable measurement standard is provided in the *Guidelines for Manual Pure Tone Audiometry*, published by the American Speech-Language-Hearing Association (1978).

Three different types of audiometers are commonly used in industrial settings. *Manual audiometers* have the lowest initial cost and permit the examiner to quickly adjust the test procedure when problems arise. In general, a manually administered hearing test takes less time and is most likely to yield valid results.

*Self-recording audiometers* require that the person who is being tested manipulate a switch that controls the intensity of the test tone. A tracing of the individual's hearing threshold is produced by recording the test level on an audiogram form as the listener adjusts the stimulus to maintain a threshold level. Testing is conducted for at least 30 seconds at each test frequency, and the proper sequence of test tones is presented automatically until the audiogram is complete. Since tests are administered automatically, several units can be operated and monitored at the same time. Thus, large industrial populations can be tested more efficiently than when audiograms are obtained manually. On the other hand, self-recording audiometers cost three to four times more than manual instruments, it usually takes longer to complete individual tests, and they cannot test everyone reliably. The likelihood of uninterpretable recordings, and the need for retesting, increases markedly when a tester must monitor more than four units at the same time.

Despite their high cost, *microprocessor-controlled audiometers* are increasingly popular in large industrial settings. These instruments are programmed to follow the same Hughson-Westlake procedures used in manual pure-tone audiometry. Consequently, test results are more reliable and easier to interpret than the tracings produced using self-recording audiometers. The primary advantage of microprocessor-controlled audiometers is that test results can be transferred electronically to a central computer where vast amounts of employee information can be stored and instantly analyzed to determine the need for follow-up hearing conservation measures and otologic audiologic referral.

OSHA does not require technicians who use microprocessor audiometers to be trained in administering and interpreting audiograms, since testing and data analysis is entirely automated and all the tester has to do in most cases is provide brief instructions, place the earphones, and press a start button. However, employers must be cautioned that all automatic audiometers (microprocessor-controlled or self-recording) fail to obtain valid results in a small percentage of workers - especially the elderly, those with manual dexterity problems, and those who speak a foreign language. All audiometric testing programs should have equipment and personnel available for administering manual evaluations when problem case arise.

In order to comply with OSHA regulations, audiometers must be calibrated and maintained in accordance with the American National Standard Specification for Audiometers, S3.6-1969. Additional specifications for self-recording audiometers are contained in the Hearing Conservation Amendment (Federal Register, 48:9780-9781). A daily listening check of all audiometers is required; the accuracy of output levels must be measured at least annually; and an exhaustive electric acoustic calibration must be performed every 2 years. Comprehensive records of all audiometer calibrations should be retained indefinitely, since they may be required as evidence when compensation claims are filed decades later.

Background noise levels in audiometric test rooms cannot exceed the octave-band values shown in Table 2. It should be noted that although these limits are adequate for industrial hearing tests, quieter test rooms are required for accurate diagnostic tests to be administered.

**Table 2. Maximum Allowable Sound Pressure Levels for Audiometric Test Rooms**

<b>Octave-Band Center Frequency (Hz)</b>	<b>Sound Pressure Level (dB)</b>
500	40
1000	40
2000	47
4000	57
8000	62

Records of each audiometric evaluation must include the employee's name and job classification, his or her most recent noise exposure assessment, the audiogram date, the examiner's name, and measurement of the background noise levels in the audiometric test room. By law, these records must be retained for the duration of the worker's employment. However, it is wise for employers to keep this information indefinitely, until there is no longer any possibility of a compensation claim.

### **Audiograms**

Within 6 months of an employee's first exposure to noise at or above 85 dBA TWA, the employer must establish a *baseline audiogram* to be used as a reference against which subsequent audiograms can be compared. Testing may be delayed an additional 6 months when mobile test vans are used, as long as workers are required to wear hearing protectors in the interim.

In order to obtain a valid audiogram, free from any temporary noise-induced hearing loss, workers must be advised to avoid high levels of noise away from the workplace, and baseline testing must be preceded by at least 14 hours of no exposure to occupational noise. This quiet period may be enforced on the job requiring employees to wear hearing protectors prior to testing. A more effective procedure is to schedule baseline testing for the start of the employee's

work shift whenever possible.

All workers exposed to noise levels at or above 85 dBA TWA must be retested at least annually. If the *annual audiogram* indicates that hearing thresholds are significantly poorer than baseline results, protective follow-up procedures are required before the hearing loss progresses. In contrast to baseline testing, no special precautions are required to avoid the possibility of temporary noise-induced hearing loss prior to the annual audiogram. In fact, the occurrence of temporary threshold shifts may lead to the early identification of noise-susceptible workers for whom hearing conservation is most important and beneficial. In order to determine whether changes in hearing thresholds are temporary or persistent, the employer has the option of retesting the worker within 30 days after the annual audiogram. This *retest audiogram* may be substituted for the annual audiogram at the employer's discretion. If the professional responsible for supervising the audiometric program determines that an employee's test results show a significant and persistent change, either for better or worse, an annual audiogram may be substituted for the original baseline audiogram as the reference for comparison with subsequent hearing tests.

Annual audiometric monitoring, as required by OSHA, is probably sufficient to detect the onset of significant noise-induced hearing changes in most workers. However, more frequent monitoring of high-risk individuals is advisable. Employees who are exposed regularly to noise levels above 100 dBA or who have shown significant hearing deterioration in the past should be reevaluated at least every 6 months until the presumption of high risk can be ruled out.

Since hearing conservation programs are intended for noise-induced hearing loss prophylaxis only, OSHA does not require hearing testing at the end of a worker's employment. However, employers are strongly advised to obtain *exit audiograms*, especially for all individuals with any history of noise exposure or hearing problems. This documentation can be used to refute compensation claims for hearing loss that actually developed following the employment period.

### **Audiogram Evaluation**

At hearings prior to OSHA's final rule-making, the American Council of Otolaryngology - Head and Neck Surgery strongly recommended that all audiograms obtained in a hearing conservation program be reviewed by an experienced otolaryngologist, other physician, or audiologist. However, OSHA had decided that "audiometric technicians, under the general supervision of an audiologist, otolaryngologist or physician have the skill necessary to review routine audiograms" (Federal Register, 48:9759). Although the supervising professional may choose to review every audiogram, this review is required only for problem audiograms, including those of questionable validity. If the employer uses technicians to evaluate test results, the supervising professional must develop a simple and effective method of identifying problem audiograms.

OSHA requires a routine evaluation of all annual audiograms to determine if the employee's hearing in either ear has deteriorated by an amount equal to the *standard threshold shift* (STS), defined as a change in threshold relative to the baseline audiogram of an average of

10 dB or more at 2000, 3000, and 4000 Hz. The contribution of aging to changes in hearing may be accounted for by applying the appropriate correction factors (developed by the National Institute for Occupational Safety and Health in 1972) to the baseline and annual audiograms before determining whether a standard threshold shift has occurred. Corrections for presbycusis are not mandatory. However, in order to eliminate the effects of presbycusis from an individual's audiogram, the correction values that apply to his or her age and sex are subtracted from the measured hearing levels. Presbycusis corrections may be used in determining whether a standard threshold shift has occurred. In some jurisdictions, they may also be used in computing the degree of hearing disability attributable to occupational noise exposure.

The OSHA STS criterion is intended to identify meaningful hearing changes at frequencies most vulnerable to noise damage without requiring unnecessary follow-up procedures for many employees. STSs should always be calculated and utilized as required by law. However, unless computations are automated, as in many computerized record-keeping systems, even well-trained technicians occasionally make errors when calculating STSs, which lead to misidentification of a significant percentage of audiograms. Furthermore, a threshold shift of up to 25 dB at one test frequency is acceptable under the OSHA STS criterion.

To minimize the possibility of overlooking significant hearing changes, a simpler and more stringent criterion for preliminary identification of problem audiograms is advisable. The best protection of employees' hearing will be obtained if all annual audiograms are referred for professional review. At a minimum, we recommend that annual audiograms be reviewed by a professional when any threshold from 1000 through 4000 Hz shows a shift of 15 dB or more relative to the baseline audiogram. The only STS, as defined by OSHA, that the 15-dB criterion would miss is a uniform 10-dB shift at 2000, 3000, and 4000 Hz. This parallel kind of threshold shift is rare and usually indicates an error in recording of data rather than progressive hearing loss (Federal Advisory Council on Occupational Safety and Health, 1984).

The professional who reviews industrial audiograms must also determine which individuals should be referred to an otolaryngologist for medical care. The American Academy of Otolaryngology - Head and Neck Surgery recommends that workers be referred whenever a threshold shift exceeds 15 dB at 500, 1000, or 2000 Hz; 20 dB at 3000 Hz; or 30 dB at 4000 or 6000 Hz (Federal Register, 48:9761).

Although threshold shift criteria will usually protect employees from progressive auditory problems after they are included in an audiometric testing program, OSHA does not require any examination of baseline audiograms for evidence of hearing loss. However, companies that ignore the initial hearing status of employees are overlooking an important opportunity to conserve their workers' hearing and to reduce future compensation claims. Otologic examinations prompted by abnormal baseline audiograms will result in the diagnosis and, when indicated, treatment of disorders that might otherwise go undetected. This offers employees an important health care benefit. The evaluation of baseline audiograms is particularly important from the employer's perspective, since hiring workers with pre-existing hearing loss can increase the risk of liability for subsequent compensation claims.

In many states, employers must compensate hearing-impaired workers only for the portion of loss incurred during their period of employment. However, the last employer may be liable for all of a claimant's hearing loss unless it can be proved that part or all of the impairment was sustained in previous work situations. Baseline audiograms are invaluable in this regard.

In other states, compensation payments for occupational hearing loss are not apportioned among all liable employers according to the amount of loss accrued during a particular employment. Instead, the last employer is liable for all of a worker's hearing loss, even if hearing test results demonstrate that part or all of the loss occurred before the employee was hired. The administration of baseline audiograms is essential to identify workers with pre-existing hearing impairments. However, employers can protect themselves from liability under these circumstances only by ensuring that compensation claims against previous employers have been adjudicated before a hearing-impaired worker is hired.

Despite all precautions to ensure that employees with pre-existing hearing loss are not assigned to hazardous noise environments, employers are still vulnerable to claims that an accidental or isolated noise exposure aggravated a worker's hearing impairment. Depending on how liability is apportioned, evidence of working conditions that aggravated a pre-existing hearing impairment in the slightest degree may result in a compensation award for part or all of the worker's hearing loss.

Many employers obtain pre-employment audiograms for all workers, and not just for those exposed to excessive noise. This practice takes full advantage of the company's hearing conservation program and maximizes protection against unwarranted compensation claims.

Any person whose baseline or pre-employment audiogram shows evidence of hearing impairment should receive an otologic examination to determine its cause. Specifically, otologic referral is indicated when the threshold average of 500, 1000, 2000, and 3000 Hz in either ear is poorer than 25 dB HL, or when the average threshold difference between ears exceeds 15 dB at 500, 1000, and 2000 Hz or 30 dB at 3000, 4000, and 6000 Hz (Dobie, 1985). Depending on the etiology and extent of the hearing loss, medical or surgical treatment, occupational counseling, and/or audiologic management may be indicated. The role of the otolaryngologist in these issues is discussed later in greater details.

### **Follow-Up Procedures**

When an annual audiogram reveals a deterioration in hearing that equals OSHA's standard threshold shift, the worker must be issued a written warning within 21 days of the STS determination. All workers with STSa are required to wear hearing protectors. Those who had already been using protectors must be refitted and retrained in their use. If subsequent testing indicates that an employee's threshold shift is not persistent, he or she must be informed of the new finding and is no longer required to use hearing protectors. In our judgment, however, these individuals should be urged to continue hearing conservation practices that have proved to be effective in protecting their hearing.

The determination of whether a worker's threshold shift is work-related is not central to the effectiveness of a hearing conservation program, according to OSHA, since the same actions are required no matter what the cause. Consequently, employers are required to refer employees for otologic examination only if they suspect "that a medical pathology of the ear is caused or aggravated by the wearing of hearing protectors" (Federal Register, 48:9777). If medical pathology is judged to be unrelated to the use of hearing protectors, employers merely need to inform the employee of the need for an otologic examination.

Employers who choose to follow OSHA's decision not to require the medical determination of etiology in all cases of standard threshold shift will have to absorb the cost of unnecessary hearing conservation measures and of unjustified compensation claims. On the other hand, companies that routinely refer such cases for otologic diagnoses will not have institute follow-up hearing conservation procedures when "a physician determines that the standard threshold shift is not work related or aggravated by occupational noise exposure" (Federal Register, 48:9777).

Furthermore, when a company's audiometric testing program identifies a progressive hearing loss that is not caused by occupational exposure to noise, it is essential to obtain a medical diagnosis in order to protect against future liability. Also, from a humanitarian and labor-relations standpoint, it is unoncsionable not to refer an employee for otologic care when his or her hearing disorder may be treated or corrected. For these reasons, the prudent and responsible employer will refer employees to an otolaryngologist whenever a hearing disorder is detected.

### **Educational Programs**

Most publications dealing with this aspect of hearing conservation discuss only employee education relative to the wearing of personal hearing protective devices. We believe that this view is too narrow and would like to emphasize the need for additional educational programs at many different levels. The topics of public education, educational programs at the industrial management level, and education of labor unions and their representatives all deserve special attention; they must not be ignored if a truly successful industrial hearing conservation program is to be established. In this section suggestions and comments are made concerning each of these topics, and they are discussed in the order in which we believe they should be implemented.

### **Public Education**

It is perhaps trite to suggest that all otologists, audiologists, and, for that matter, anyone else responsible for the delivery of hearing health care (whether or not they are directly involved in industrial hearing conservation) must be constantly emphasizing and dispensing information to create and enhance public awareness of noise as a hazard to hearing. With all the publicity concerning the hazardous effects of noise and the tremendous public concern with environmental pollutants that has occurred over recent years, the physician and audiologist must continue to emphasize to the public that hearing is a necessary function rather than an expandable commodity, and that its normal function need not be jeopardized by hazardous levels of noise.

Increased public awareness and concern is one of the most effective methods for promoting industrial hearing conservation programs.

### **Education of Management**

Educational programs at the management level should be viewed as an ongoing process, and obviously these programs will differ from plant to plant and from industry to industry. The first level of managerial involvement is in the planning and organization of the hearing conservation. Depending on the level of expertise of those at the management level, educational programs might need to include information on the function of the ear, the effects of noise-induced permanent hearing loss, and detailed explanation of the hearing testing and personal hearing protection device programs.

Managerial personnel must scrupulously follow the hearing conservation regulations set up for their employees, in order to provide a highly visible example of the importance of compliance. For instance, managers should never enter a hazardous noise area, even for a moment, without first putting on hearing protectors. When management ignores required safety practices, labor will too.

The support of management is obviously essential to the smooth operation of a successful hearing conservation program, and the more management is aware of what is going on with the program, the more supportive it will be. Therefore, it is suggested that meetings of management with all personnel responsible for the design and implementation of the hearing conservation program should occur regularly, or at least at the completion of each part of the hearing conservation program.

### **Labor Union Education**

If the labor force of a particular company or plant is organized, it is suggested that an educational program be established for the officials and/or safety representatives of the specific union(s). Because of the power and influence wielded by today's unions, their support of the hearing conservation program will promote acceptance on the part of the workers. This support can be gained by holding a special session or sessions with the unions before the employee educational program, audiometric testing, and personal hearing protection equipment program are introduced to the workers.

At the start of the first meeting with union officials, it is important that those responsible for the organization, implementation, and supervision of the hearing conservation program present their backgrounds and qualifications. In addition, the following topics need to be discussed with union leaders, allowing as much time as necessary to clarify issues and answer questions: outline of the basic program, audiometric testing and interpretation, and record keeping.

Care must be taken to describe the qualifications of those doing the hearing testing, to explain how and where records are kept, and to emphasize that the employee always has access



to these records. Finally, union representatives are usually interested in knowing whether the employee is informed of test results, and whether, based on the results, the employee's job security will be at risk. If these matters are discussed thoroughly, and if adequate time is allowed to answer all questions and talk about any other aspects of the program that need to be covered, union acceptance and endorsement of the hearing conservation program is essentially assured.

### **Education of Employees**

The cornerstone of any effective and successful program is employee education. OSHA requires employers to conduct annual training for all workers included in the hearing conservation program. At a minimum, the information provided must cover the effects of noise on hearing, the purpose and use of hearing protectors, and the methods and objectives of audiometric testing (Federal Register, 48:9778). In addition, employees should also be educated about the provisions of hearing conservation regulations that affect them, specific machinery in the workplace that could produce hazardous levels of noise, and the implementation of engineering and administrative noise controls. Care must be taken to ensure that all employees are included in these sessions, regardless of the shift that they work on their particular job location in the plant. Again, it is important to emphasize that sufficient time be allowed to answer all workers' questions.

### **Enforcement, Penalties, and Workers' Compensation**

In 1985, almost 221 million dollars was appropriated for OSHA. About 20 per cent of this amount was spent on the development of safety, health, and compliance standards; and 60 per cent funded federal and state enforcement efforts. During that year, 71,400 federal and 108,000 state inspections were supported by OSHA. Budget requests for 1986 include a 7.7 million dollar cut in funding for OSHA, the majority of which will be absorbed in the areas of standards development and federal enforcement. This development will no doubt affect the agency's ability to implement and enforce its occupational noise regulations.

Even under the best of circumstances, OSHA's ability to ensure that worker's hearing is protected is limited. Since a moratorium on enforcement of hearing conservation regulations was in effect for most of fiscal year 1985, full enforcement efforts were pursued only in the fourth quarter. During this period, a total of 599 noise violations were cited by inspectors. Five of these were judged to be willful, and 108 were serious violations.

The OSHAct of 1970 specifies that employers who willfully or repeatedly violate safety and health regulations may be assessed a civil penalty of not more than \$10,000 for each violation. Less serious violations are subject to a maximum penalty of \$1,000. In practice, after adjustments and adjudication, a *total* of \$8141 in penalties was imposed during the fourth quarter of 1985. Clearly, such penalties are not yet a strong inducement for industry to comply with OSHA regulations.

Although OSHA regulations were an important stimulus for the development of hearing conservation programs, it is the increase in the amount of compensation paid for occupational hearing losses that has fueled their growth. Since 1977, 31 states have shown an increase in the number of hearing loss compensation claims (Shampan, 1985). Although only five states paid more than 100 hearing loss claims in 1977, more than a dozen states exceeded that number in just the first 5 months of 1985. In 1983-1984, the top five states in number of claims paid were Wisconsin (796 claims), New York (787), New Jersey (587), West Virginia (491), and Washington (385).

The dollar amount of claims has increased as well. In 1977, the most generous benefit limit was \$55,380. Iowa now has a maximum allowable benefit of \$90,000 - the highest of all states. Pennsylvania and Michigan are close behind with \$85,000 maximum benefits. Although maximum benefit levels have increased substantially, most awards are still concentrated at the lower end of the compensation benefit scale. In 1983-1984, the states paying the highest average claim were Ohio (average claim, \$5600), Washington (\$4800), and North Carolina (\$3500).

Many employers have been slow to implement hearing conservation programs, possibly because they fear that hearing testing and worker access to medical records might increase compensation claims. In fact, one study of federal claims indicates that awards are more than \$1000 lower when employers can provide hearing test results than when such documentation is lacking (Ginnold, 1979).

OSHA estimates that the total annual cost of mandated hearing conservation programs is 210.3 million dollars, which is about \$41 per included worker (Federal Register, 48:9741). It is projected that once these programs have been in effect for 10 years, they will eliminate 212,000 cases of "material" hearing impairment. In contrast, over the 10-year period from 1977 to 1987, federal and state compensation payments for occupational hearing loss exceeded \$2.5 billion dollars (Shampan and Ginnold, 1983, p 313). The impetus for developing and improving hearing conservation programs will increase as more companies realize that such efforts have a tangible payoff in terms of reduced workers' compensation costs.

### **The Role of the Otolaryngologist in Industrial Hearing Conservation Programs**

As stated previously, we advocate that every industrial hearing conservation program have full medical supervision. In practice, the degree of otolaryngologists' involvement in industrial hearing conservation ranges from direction of program development and administration to a very limited role as a consultant and/or referral source. Although OSHA requires medical evaluations only when pathology interferes with the wearing of hearing protectors, the importance of the otolaryngologist as a hearing conservation professional is firmly established by several specific references in the OSHA Act.

First, the otolaryngologist is identified as one appropriate professional to supervise the entire audiometric testing program. In this capacity, he or she would be responsible for reviewing and interpreting audiograms to determine the need for additional medical, audiologic, or hearing

conservation action. Also, the value of otologic diagnosis and treatment is acknowledged by the provisions exempting employers from instituting follow-up hearing conservation measures when a physician determines that a threshold shift is not work-related, and by the requirement that workers with medical pathology at least be informed of the need for an otologic examination. These guidelines create a golden opportunity to educate employers about the role of otolaryngologist: namely, in addition to diagnosing and treating otic disease, the otolaryngologist can provide occupational counseling, rehabilitative guidance, and medicolegal expertise, which is essential to the success of any hearing conservation program. Once the importance of these services is demonstrated, the otolaryngologist will become indispensable to both management and labor.

### **Implications of Permissible Noise Exposure Limits**

Otolaryngologists usually are not directly involved in measuring noise levels. However, noise surveys are often initiated by medical findings that indicate the possibility of a hazard. The American Academy of Otolaryngology - Head and Neck Surgery (1982) has identified the following as indicators of hazardous noise:

1. Difficulty in communication by speech while in a noisy area (ie, difficulty understanding normal face-to-face communication at a distance of 2 feet).
2. Head noises or ringing in the ears after working in a noisy area for several hours.
3. A temporary loss of hearing that has the effect of changing a person's perception of sound after several hours of exposure to noise.

When the physician's information indicates that any worker's exposure to noise may be excessive, he or she should advise the employer to survey the noise levels at the work site and institute hearing conservation measures if they are indicated.

Familiarity with OSHA permissible noise exposure limits may assist the otolaryngologist in determining, for compensation or other purposes, whether an individual's hearing impairment is job-related. These standards are intended to protect the majority of workers from sustaining material hearing impairment, by setting practical noise limits that are technologically and economically feasible. Inherent in this compromise between protection and feasibility is an acceptance of residual risk.

In fact, after 21 to 41 years of noise exposure, the prevalence of hearing loss is 25 per cent higher for TWA noise levels of 90 dBA than when noise levels are below 80 dBA TWA (National Institute for Occupational Safety and Health, 1972). Thus, noise exposures that are legally acceptable are not necessarily biologically safe. In the final analysis, although noise exposure regulations may be of some assistance, the diagnosis of occupational hearing loss depends on the clinical expertise of the otolaryngologist.

## **Diagnosis and Treatment of Hearing Loss**

Emphasis must be placed upon medical diagnosis in the initial evaluation (pre-employment or baseline) as well as during the monitoring phases of the noise exposure. About 3 per cent of baseline audiograms show abnormalities that warrant otologic referral, and hearing loss is found to be unrelated to occupational noise exposure in about half of these cases (Dobie and Archer, 1981). Even though an industrial hearing test is only a screening measure, findings such as unilateral hearing loss, low frequency hearing loss, or unusual audiometric patterns demand examination and treatment.

A hearing conservation program cannot require that an employee subject himself to further medical examination and/or treatment unless a pathologic condition of the ear is caused or aggravated by the wearing of hearing protectors. When other types of hearing disorders are discovered, employers are wise to use all possible means to encourage workers to obtain otologic care. The best way to do this is for the company or insurance carrier to pay for the otologic examination. When employees must bear the cost themselves, less than 50 per cent will follow the recommendation to obtain an otologic examination (Harford, 1978). Any employee who refuses to seek medical consultation should be required to sign a waiver stating that the results of his hearing tests and the need for diagnosis and possible treatment have been explained to him.

Monitoring hearing testing will help to demonstrate whether hearing levels are degenerating. Otologic referrals are indicated for 1 to 2 per cent of workers retested annually in hearing conservation programs (Dobie and Archer, 1981). These employees should be examined by a physician whose responsibility is to determine whether the reason for the deterioration of hearing levels is medical or occupational. Although the determination of causality is not required by OSHA, it will improve employee health care and will protect the employer from unjustified compensation claims.

Otologic opinion is of utmost importance in trying to determine causal relationships between noise exposure and hearing loss. This opinion should be based on the following considerations:

1. The history of the hearing loss, including the onset and progress of the loss.
2. An occupational history, including dates, types of work, and so forth.
3. Noise studies demonstrating that the noise is of a type and of sufficient intensity and duration to cause hearing loss.
4. Results of the otologic examination.
5. Results of audiologic and hearing status studies, including pre-employment, periodic, and termination tests.

6. Ruling out of nonindustrial causes of the hearing loss, including presbycusis, sociocusis, ototoxicity, and so forth.

Once a diagnosis has been established, proper treatment may then be initiated. If the reason for the change in hearing is not medical, other causes can be considered: absence of ear protection devices or improperly fitting or improperly worn devices, inadequate engineering controls to reduce noise at its source, and inadequate administrative efforts to control the amount of exposure to noise.

In cases that are not medically or surgically treatable, the otolaryngologist must determine if a program of aural rehabilitation is appropriate. In one study (Dobie and Archer, 1981), otolaryngologists who received referrals from hearing conservation programs recommended hearing aid evaluations and/or other aural rehabilitation for only about one-third of workers whose pure-tone thresholds averaged 40 dB HL or more. This was attributed, at least in part, to otolaryngologists' varying degrees of enthusiasm for hearing aids. This is unfortunate, since the great majority of persons with this degree of hearing loss, or even with milder losses, can benefit from the frequency-selective amplification provided by modern hearing aids.

In order to foster reasonable expectations for aural rehabilitation, the potential candidate should be counseled about the advantages and limitations of hearing-aid use. Guidance to competent audiologic services is equally important, especially for patients with special problems like loudness intolerance or severely reduced speech discrimination capacity.

### **Occupational Counseling**

Counseling involves many ambiguities and is probably the most difficult area with which the otolaryngologist must deal. Difficulties here are usually due to the lack of concrete experimental results concerning the nature of noise-induced hearing loss, and the fact that the physician must make suggestions based on very little previous evidence. For example, should the physician recommend that an employee with diagnosed noise-induced hearing loss return to a noisy work environment and risk further damage? Or should he or she recommend that another employee with normal hearing be placed in that environment at the risk of developing hearing impairment? The answers are unclear because of insufficient data concerning susceptibility to noise-induced hearing loss, and because of the differential rate of growth of permanent hearing loss at higher frequencies compared with the relatively slow growth of loss in the "speech frequencies".

Pre-existing sensorineural hearing loss whose origin is *not* noise-induced also presents a problem. Sataloff and Vassalo (1969) state that, without exception, those persons with sensorineural hearing losses that are progressive in nature should be excluded from employment in noisy areas. This rationale is based on experimental evidence that shows an additive effect of noise-induced hearing loss and other etiologies, such as ototoxicity, heredity, and infection.

The physician must decide whether to advise complete exclusion of the person with mild non-noise-induced sensorineural loss from noisy environments or to recommend merely that the person's hearing be evaluated on a frequent routine basis in order to check for evidence of progression of the loss. On the other hand, it is probably advisable to suggest that persons with anything more than a mild hearing loss seek employment in which there are safe levels of noise, so that there is no risk to their residual hearing. Finally, it is usually prudent to suggest that anyone who must wear a hearing aid not work in areas of high concentration of noise.

The situation of a conductive hearing loss presents some unusual and interesting considerations. It must be realized that a conductive hearing loss protects the inner ear from damage due to loud noise much the same as a well-fitting earplug or earmuff. Therefore, as long as the conductive problem is medically supervised and followed, and as long as the amount of hearing loss does not pose a safety threat to the individual or to others, the presence of a conductive hearing loss should not necessarily exclude an employee from working in a noisy environment. However, since many conductive hearing losses are medically or surgically treatable, and since many of the etiologies of conductive hearing loss are progressive and destructive in nature, the importance of medical participation in the industrial hearing conservation program is again emphasized.

Physicians involved in occupational counseling must be aware that union rules sometimes complicate efforts to protect employees whose hearing is jeopardized by exposure to noise. For example, one way to reduce exposure to noise is to rotate workers between safe and hazardous environments over the course of the day, so that each individual is exposed for only a portion of the work shift. However, labor agreements often require employers to pay each worker who spends even a short period of time exposed to intense noise as if he or she had spent a full 8-hour shift in the hazardous environment. Since workers in hazardous jobs usually are paid high wages, such labor restrictions tend to discourage employers from implementing simple and effective administrative noise controls like employee rotation.

### **Medicolegal Responsibilities**

Although in most respects hearing conservation programs involve the coordinated efforts of a variety of professionals, the physician must bear the medicolegal burden when issues of liability for occupational hearing loss arise. This is a major justification for requiring medical supervision of efforts to conserve workers's hearing.

When an otolaryngologist provides direct supervision, it enhances the validity of hearing test procedures, audiometric records, referral decisions, hearing protector evaluations, and so on. Thus, medical authority effectively reduces the employer's liability risk. By providing an accurate and timely diagnosis of hearing disorders caused by factors other than industrial noise, the otolaryngologist provides employers with additional protection from unwarranted compensation claims.

If a hearing loss develops because an employee was exposed to high levels of noise, or if a pre-existing hearing loss was complicated owing to the noise, the medical probability exists that the hearing loss is due to the exposure to noise if there is no nonoccupational etiology for the hearing loss and if the hearing loss is of the sensory type associated with exposure to noise. In this case, according to law, the worker is entitled to the maximum compensation due him or her. It then becomes the responsibility of the otolaryngologist to determine the amount of disability attributable to occupational exposure to noise.

As has been stated, the determination of hearing disability must be based on audiometric test results obtained after the worker has been removed from any exposure to noise for at least 14 to 16 hours, in order to eliminate any effects of temporary threshold shift. Many different hearing disability rating systems are in current use. The procedures used by the DOL's Office of Workers' Compensation Programs (OWCP) to rate the disability of federal employees are the only ones applied nationally. According to the OWCP formula, compensable hearing disability begins when the average of hearing thresholds at 1000, 2000, and 3000 Hz exceeds a *low fence* of 25 dB HL.

The hearing handicap rating increases 1.5 per cent for every dB of average hearing loss beyond the low fence. The rating equals 100 per cent impairment when the average threshold reaches a *high fence* of 92 dB HL. In order to quantify the degree of binaural impairment, the *percent of binaural impairment* (PBI) is calculated by giving the percentage obtained for the better ear a weighting of 5 before it is averaged with the poorer ear's percentage of impairment. That is, to calculate PBI, the better ear's percentage is multiplied by 5 and added to the poorer ear's percentage; the total is then divided by 6.

In the USA, the policies and procedures that govern the determination of hearing disability vary widely from state to state. In some states, hearing thresholds may be adjusted to account for presbycusis before PBI is computed. The age corrections shown are widely used for this purpose. Some states compensate for losses in speech discrimination ability or for tinnitus. Others pay compensation only in cases of "total" hearing disability. Frequent legislative and judicial revisions of compensation practices further complicate matters. Thus, anyone interested in the percentage of hearing loss or amount of compensation must research the specific rules that apply to the individual case. No matter how professional or accurate a determination of the amount of hearing an employee has lost, such a determination does not supersede state law and may or may not result in appropriate compensation.

### **The Role of the Audiologist in Industrial Hearing Conservation Programs**

Relatively few audiologists are employed full-time in industrial hearing conservation programs. More frequently, they serve as consultants. The industrial audiologist's responsibilities may include evaluating noise levels, documenting the attenuation provided by personal hearing protectors, and providing quality control to maximize the validity and reliability of audiometric test results.

## **Identification of Noise Hazards**

The industrial audiologist should be capable of conducting a noise survey. The finalized hearing conservation amendment of OSHA requires employers to monitor noise exposure levels in a manner that will accurately identify employees who are exposed at or above an 85 dBA TWA for 8 hours. All continuous, intermittent, and impulsive sound levels from 80 dBA to 130 dBA must be integrated into the noise measurements. Monitoring must be repeated whenever a change in production process, equipment, or controls increases levels of noise exposure to the extent that new or additional hazards are created. As long as these performance goals are met, the amendment allows the employer to choose his own method for achieving compliance. This approach is in marked contrast to the detailed specifications of equipment characteristics and calibration, monitoring procedures, remonitoring schedules, and other requirements that characterized previous interim and proposed regulations of OSHA. Professionals who perform noise exposure measurements now have the flexibility to use whatever equipment and procedures are best suited to the unique circumstances and problems of the workplace. Concomitantly, they also have an increased responsibility for ensuring that the obtained measurements comply with the obligations imposed by the amendment. One good way to assure compliance is to use the same methods recommended for federal agencies by the Federal Advisory Council on Occupational Safety and Health (1984).

## **Measurement of Attenuation by Hearing Protectors**

Companies that rely on personal protective equipment as a means of noise control must ensure that the devices are attenuating noise levels to within permissible exposure limits. As described previously, NRRs may be used to estimate attenuation values. However, this technique does not account for the large individual differences in attenuation that occur when workers actually use hearing protectors in the workplace. In fact, field studies show that as many as 10 per cent of workers receive less than 3 dB of attenuation from hearing protectors (Lempert and Edwards, 1983). Because of the variability of protectors' performance in real use, some workers may remain at risk for noise-induced hearing loss despite their full compliance with noise control regulations. A more direct way to determine actual attenuation is to measure each employee's audiometric thresholds with and without hearing protectors in place. According to current standards (ANSI S3.19-1974) these measurements should be obtained in a reverberant test environment with third-octave bands of noise as the test stimuli. The protection provided by a particular device at different frequency regions can then be found by calculating the difference between the individual's protected and unprotected thresholds.

At present, audiometric measurements of functional attenuation are the most accurate way to evaluate the adequacy of personal hearing protectors in individual cases. This type of individual evaluation is highly recommended, especially when employers rely on personal protective equipment to reduce workers' noise exposure levels by 10 dB or more. Since these evaluations require special equipment and technical expertise, they should be administered by an audiologist.



## **Audiometric Quality Control**

The relatively high test-retest variability of industrial audiograms is well documented (Dobie, 1985). The main sources of this variability include technicians with inadequate training or supervision, changes in test procedures or equipment from audiogram to audiogram, and faulty calibration practices and documentation. The audiologist's expertise can do much to reduce these potential problems.

The audiologist is the professional best qualified to train technicians to administer industrial hearing tests properly. Even when microprocessor-controlled audiometers are used, technicians must be trained in administering instructions, detecting inappropriate test responses, and recognizing equipment malfunctions. If experienced or CADHC-certified technicians are already employed in the audiometric testing program, the audiologist must establish a standard protocol for all testing and make sure that examiners adhere to it.

Over the course of a periodic audiometric testing program, the variability of test results will be reduced if an individual is always tested with the same audiometer. This is especially important when a program uses both manual and automatic instrumentation, since different types of audiometers do not always yield comparable results. If at some point replacement of equipment causes a complete shift from reliance on one type of audiometer to another, it may be advisable to substitute audiograms obtained with the new equipment for the original baseline audiograms.

It is essential to maintain a strict calibration schedule for all audiometers used in the testing program. Ideally, the accuracy of output levels should be validated by sound level measurements each day that an audiometer is in use. If this is impossible, daily calibration checks must include testing an individual whose hearing thresholds are known and stable (Federal Register, 48:9778). Data from several listeners should be obtained to ensure that alternate biological calibration test subjects are available if one individual is ill or absent. These listeners should have thresholds in the range of 10 to 25 dB HL, so that a bracketing technique can be used for all measurements. Reference thresholds for each listener used in biological calibrations should be determined by averaging a minimum of 10 repeated measurements obtained on different days. If the results obtained from a daily listening check deviate by 10 dB or more from these reference thresholds, the audiometer should be removed from service until it is recalibrated.

Rough handling during shipping can cause changes in audiometer performance. Consequently, electroacoustic calibration should be performed on-site whenever possible. Since modern audiometers are generally quite stable in normal use, calibration adjustments should be made only when audiometer characteristics do not meet the tolerances allowed by the ANSI-1969 standard and by OSHA (Federal Register, 48:9781). Unnecessary, minor adjustments of audiometer calibration may have a substantial effect on the number of employees who subsequently show threshold shifts (Royster, 1985).

All audiometric calibrations must be documented by meticulous records. Measurements should be recorded both before and after any calibration adjustments are made. Calibration records should be retained indefinitely, since that may be required to support the validity of audiograms submitted as evidence in compensation cases.

### **The Future**

For almost two decades, efforts to reduce the hazard of industrial exposure to noise were mired in conflict and controversy. Now, finally, all the major elements that constitute an effective industrial hearing conservation program have been codified into law. Hopefully, this resolution of the competing interests of management, labor, and health care professionals will foster cooperative and constructive action. Hearing conservation programs hold the promise of eliminating one of the most insidious, widespread, and costly hazards in our industrial society. In order to bring this promise to fruition, otolaryngology must take a leading role in the prevention of occupational hearing loss.