CHAPTER 5

Hearing Loss Prevention Programs (HLPPs)

Whenever hazardous noise exists in the workplace, measures should be taken to reduce noise levels as much as possible to protect exposed workers and to monitor the effectiveness of these intervention processes. Employers have an obligation to protect their workers from this debilitating occupational hazard [46 Fed. Reg. 4078 (1981a); 48 Fed. Reg. 9738 (1983)]. In addition, research has shown that implementing effective HLPPs (also known as hearing conservation programs) has numerous other benefits in the workplace [NIOSH 1996]. For example, Cohen [1976] found reduced employee absenteeism following the establishment of a hearing conservation program. Similarly, Schmidt et al. [1980] reported a reduction in workplace injuries following the introduction of a hearing conservation program. Alternatively, other reports have documented detrimental nonauditory effects of noise, such as decreased productivity in high noise environments [Noweir 1984; Suter 1992b]. Employers who effectively protect their workers' hearing may also reap the economic benefits of lower workers' compensation rates because of fewer claims for NIHL.

NIOSH recommends that HLPPs be implemented for all workers whose unprotected 8-hr TWA exposures (i.e., exposures incurred without the use of hearing protectors) equal or exceed 85 dBA and that the programs include at least the following components [NIOSH 1996]:

1. Initial and annual audits of procedures

2. Assessment of noise exposures

3. Engineering or administrative control of noise exposures

4. Audiometric evaluation and monitoring of workers' hearing

5. Use of hearing protectors for exposures equal to or greater than 85 dBA, regardless of exposure duration

6. Education and motivation of workers

7. Recordkeeping

8. Program evaluation for effectiveness

Today, no legitimate reason exists for any worker to incur an occupational hearing loss [NIOSH 1996]. Implementation of an HLPP must hinge on the fact that occupational NIHL is 100% preventable. The key to developing and implementing an effective program lies in a commitment by both management and workers to prevent hearing loss [Helmkamp et al. 1984]. This end is facilitated by integrating the HLPP into the company's overall health and safety program [Berger 1981; NIOSH 1996]. This step gives the prevention of hearing loss the same weight as the prevention of other work-related illnesses and injuries, thus indicating to workers and management that occupational hearing loss must be taken seriously. Other factors that facilitate an effective HLPP include encouraging workers to carry over their good hearing conservation practices to off-the-job situations; using simple, clearly-defined procedures; making compliance with the HLPP a condition of employment; and incorporating safety requirements into written company policy.

5.1 Personnel Requirements

Responsibility for developing and implementing an HLPP usually resides with a team of professionals. The American Occupational Medical Association (AOMA) [1987] identifies the team approach to hearing conservation as necessary for its success. The number of team members and their professional disciplines may vary with the kind of company and the number of noise-exposed workers; however, members frequently include audiologists, physicians, occupational health nurses, occupational hearing conservationists, engineers, industrial hygienists, safety professionals, management representatives, and employee and union safety representatives.

Regardless of whether program responsibility resides with a team or a single individual, one person should act as champion for the program, maintaining overall responsibility for its implementation [NIOSH 1996; Royster and Royster 1990]. This individual will be referred to in this document as the "program implementor." The program implementor should ensure that all aspects of the program are fully and properly administered and should enlist the support of management and workers in actively preventing hearing loss. Royster and Royster [1990] recommend that the primary qualification of the program implementor be a genuine interest in preserving workers' hearing. AOMA [1987] recommends that the program implementor be a physician. NIOSH [1996] maintains that the professional discipline of the program implementor is not as important as his or her ability to act as the champion of the HLPP by focusing management and worker attention on hearing conservation issues. In addition, the program implementor's stature in the organization should allow him or her to make decisions, correct deficiencies, enforce compliance, and supervise other team members with regard to the program.

In addition to the program implementor, one person should be responsible for the audiometric aspects of the HLPP; this person will be referred to in this document as the "audiometric manager." The professional qualifications of this person are critical. The audiometric manager should be an audiologist or a physician specializing in otological or occupational medicine. The program implementor and the audiometric manager may

be the same person—provided that he or she meets the qualifications for both positions. If the program implementor and the audiometric manager are not the same person, the audiometric manager should report to the program implementor, regardless of the professional credentials of either party.

5.2 Initial and Annual Audits (Component 1)

Ideally, an initial audit should be conducted before an HLPP is implemented or any changes are made to an existing program. This audit will serve as a basis for assessing the effectiveness of an improved program. The audit should begin by examining administrative issues such as corporate responses to safety and health regulations, official policies promoting good safety and health practices, assurance of adequate resources to conduct the program, and the status of the program implementor within the company. Current engineering and administrative controls should be evaluated, and the systems for monitoring noise exposures and conducting audiometry should be critically examined. Employee and management training should be noted, and past successes and failures should be analyzed so that improvements can be made. In particular, if engineering and administrative controls are insufficient, auditors should note whether effective training is provided in the selection, fitting, and daily use of hearing protectors. Recordkeeping procedures should be inspected meticulously because methods for maintaining records of audiometry, noise exposure, and other aspects of the overall program can greatly influence the success or failure of a program. NIOSH recommends that an HLPP audit be conducted annually as a part of an overall program evaluation so that the strengths of the program may be clearly identified and weaknesses promptly addressed [NIOSH 1996].

5.3 Exposure Assessment (Component 2)

Section 6(b)(7) of the Occupational Safety and Health Act of 1970 [29 USC 651 et seq.] requires that, where appropriate, occupational health standards provide for monitoring or measuring employee exposure at the locations and intervals and in the manner necessary for the protection of employees. Accurate characterization of the noise hazard present in the workplace and the subsequent identification of affected workers are both extremely important. These two elements form the basis for all subsequent actions within the HLPP [NIOSH 1996]. Monitoring procedures should be specifically defined to ensure consistency. Instrumentation, calibration, measurement parameters, and methods for linking results to worker records should be clearly delineated. Exposure assessment should be done during typical production cycles; however, if noise levels vary significantly during different phases of production, then exposures should be assessed separately for each phase [Royster and Royster 1990; NIOSH 1996].

Exposure assessment should be conducted by an industrial hygienist, audiologist, or other professional with appropriate training [NIOSH 1996]. Workers should be permitted and encouraged to observe and participate in monitoring activities insofar as such observation

or participation does not interfere with the monitoring procedure. Their participation will help ensure valid results, as the workers frequently have the experience to identify the prevailing noise sources, indicate periods when noise exposure may differ, and recognize whether given noise levels are typical or atypical. They can explain how different operating modes affect equipment sound levels and they can describe worker tasks and positions. The cooperation of workers is also critical to ensure that workers do not advertently or inadvertently interfere with obtaining valid measurements. The initial exposure monitoring can serve as an introduction to the HLPP by raising the awareness of workers and management regarding noise as a hazard. The monitoring survey, if conducted cooperatively, can help establish a rapport that will help obtain the cooperation of both workers and essential management in later phases of the program [Royster and Royster 1990; NIOSH 1996].

The frequency with which noise exposure assessments are updated depends on several variables. These might include the intensity of the noise, potential changes in exposure due to changes in equipment or production, the rate of significant threshold shift noted among workers, other changes noted in additional measures of program effectiveness, requirements of various governmental regulations, workers' compensation requirements of individual States, union contract stipulations, and specific company policies [Royster et al. 1986].

In general, after the initial exposure assessment, NIOSH [1996] recommends that exposure monitoring be repeated periodically—at least every 2 years for noise levels equal to or greater than 95 dBA and at least every 5 years for noise levels less than 95 dBA. Periodic noise monitoring will identify situations where the noise levels have changed because of, for example, aging equipment, equipment with maintenance problems, and undocumented process changes. Monitoring shall be repeated sooner if a change in production, process, equipment, or personnel might affect exposure levels [Royster et al. 1986; Royster and Royster 1990; NIOSH 1996].

Workers shall be notified of the noise exposure level determined for their particular job and the relative risk that such an exposure poses to their hearing. This information should also be cross-referenced to individual worker records. Notification should include a description of the specific hazardous noise sources in the worker's area, the purpose and proper use of any noise control devices, and requirements for hearing protectors, if appropriate. This notification can be incorporated into the worker training program [Royster and Royster 1990; NIOSH 1996]. The notification may also be posted in the work area. Noise contour maps may be posted and readily available for the entire facility, so that workers may be made aware of the noise levels in other areas. In cases where noise is due to a process, notification may include a list of noise-hazardous processes.

At a minimum, warning signs should be posted on the periphery of noise areas [Royster and Royster 1990; NIOSH 1996]. The warning signs should include a requirement that hearing protectors be worn in the area, and a supply of several types of hearing protectors should be readily accessible. Signs should communicate to workers graphically and

should be printed in English and in the predominant language of the workers who do not read English.

5.4 Engineering and Administrative Controls (Component 3)

For occupational hearing loss prevention, NIOSH defines *engineering control* as "any modification or replacement of equipment, or related physical change at the noise source or along the transmission path (with the exception of hearing protectors) that reduces the noise level at the employee's ear" [NIOSH 1996]. Typical mechanisms for engineering noise controls include reducing noise at the source (installing a muffler), altering the noise path (building an acoustic enclosure or barrier), reducing reverberation (covering walls with sound-absorbing materials), and reducing equipment vibration (installing vibration mounts). Engineering controls should be the first order of protection from excessive noise exposure [46 Fed. Reg. 4078 (1981a); Suter 1986; AOMA 1987]. When the noise can be reduced or eliminated through engineering controls, the danger to hearing is also reduced or eliminated. Where periodic noise monitoring is conducted, the feasibility of employing engineering controls should be reevaluated, with priority given to noise sources that affect the greatest number of workers. *Any* reduction in noise level (even if it is only a few decibels) serves to make the noise hazard more manageable, reduces the risk of hearing loss, improves communication, and lowers annoyance and related extra-auditory problems associated with high noise levels [NIOSH 1996]. Furthermore, when the noise can be reduced to acceptable levels through engineering controls, employers may forego some of the additional difficulties and expenses related to providing hearing protectors, education and motivation programs, and program evaluation [Royster and Royster 1990].

To reduce noise in an existing facility, it is generally necessary to retrofit engineering controls. Development of these controls should involve engineers, safety and industrial hygiene personnel, and the workers who operate, service, and maintain the equipment. Development of special noise control measures must be predicated on a thorough assessment of the noise source and individual worker exposure. Consideration should be given to the relative contribution of each noise source to the overall sound levels. Various noise control options should be evaluated on the basis of their effectiveness, cost, technical feasibility, and implications for equipment use, service, and maintenance. Other potential complications of new noise control measures (such as effects on lighting, heat production, ventilation, and ergonomics) should be considered [NIOSH 1996]. Engineering controls must always consider the proper maintenance of equipment. In addition, the function and purpose of any planned or existing engineering controls should be fully discussed with the workers so that they support the controls and do not inadvertently interfere with them [NIOSH 1996].

Management should also consider noise reduction when planning for new or remodeled facilities. Engineering controls can be most effective when they are incorporated into the design and purchase of equipment from the start. In addition, the cost of incorporating engineering controls during the design phase is generally much lower than

retrofitting them at a later date. The ultimate noise level can be substantially reduced by substituting more sound-absorbent materials, modifying equipment structure or mechanical processes, and isolating sources within the equipment [Haag 1988a].

A "buy-quiet" policy for new equipment acquisitions should be adopted by management [Royster and Royster 1990; Brogan and Anderson 1994; NIOSH 1996]. Haag [1988b] describes a four-part process that management can implement to have an effective buy-quiet policy. The process includes selecting products or operations to be targeted for noise reduction through new purchases, setting criteria for new equipment noise levels, requesting noise level specifications from manufacturers, and including these noise level data in bid evaluation. Again, input from workers should be incorporated into the buying process.

When engineering controls are inadequate, supplemental administrative controls may be utilized to help limit exposures. *Administrative controls* are defined as changes in the work schedule or operations that reduce worker noise exposures. For example, sometimes workers can be scheduled so that their time in a noisy environment is minimized. When extremely noisy operations are unavoidable, the number of workers permitted to work in such an environment should be minimized. In all cases, the application of administrative controls should not result in exposing more workers to noise. Finally, a quiet, clean, and conveniently located lunch and break area should be provided to give workers periodic relief from workplace noise.

5.5 Audiometric Evaluation and Monitoring (Component 4)

Audiometric evaluation of workers' hearing is crucial to the success of an HLPP because it is the only way to actually determine whether occupational hearing loss is being prevented. Because occupational hearing loss occurs gradually, affected employees often notice no change in hearing ability until a relatively large change in their hearing sensitivity has occurred. The annual comparison of audiometric tests can trigger prompt hearing loss program interventions, initiating protective measures and motivating employees to prevent further hearing loss.

5.5.1 Audiometry

Audiometry shall be conducted by an audiologist, a physician, or by an occupational hearing conservationist certified by the CAOHC or the equivalent. All testing shall be supervised by an audiologist, an otologist, or an occupational physician. Occupational hearing conservationists should follow the training guidelines proposed by the National Hearing Conservation Association (NHCA) [1987]. Use of microprocessor-based or self-recording audiometers should not waive the qualification requirements for the tester.

For audiometric testing to be beneficial, management must allocate sufficient time and resources to allow for timely and accurate testing. The testing must be conducted

carefully to ensure the integrity of the audiometric data. Effective communication and coordination are critical among management, health service providers, and workers.

Audiometry shall, at a minimum, consist of pure-tone air-conduction threshold testing of each ear at 500, 1000, 2000, 3000, 4000, and 6000 Hz. Although this entire frequency range is not used in the assessment of OSHA's standard threshold shift (STS), all of these frequencies are important in deciding the probable etiology of a hearing loss. To enhance the decision about probable etiology, testing at 8000 Hz should also be considered. Sufficient time should be taken to conduct the test accurately. Testing too quickly sacrifices accuracy and gives the worker the impression that audiometry and the HLPP are unimportant [NIOSH 1996].

Audiograms are displayed and stored as tables or charts of hearing thresholds measured in each ear at specified test frequencies. In OSHA-mandated hearing conservation programs, thresholds must be measured for pure-tone signals at the test frequencies of 500, 1000, 2000, 3000, 4000, and 6000 Hz [29 CFR 1910.95(h)(1)]. At each frequency, the threshold recorded for an ear is the lowest signal output level of the audiometer at which the individual responds in a specified percentage of trials (such as 50%) or in two of three trials. Hearing thresholds are measured in dB HTL (decibels, hearing threshold level), with 0 dB HTL representing average hearing ability for young people with no otological pathology.* Larger threshold values indicate poorer-than-average hearing; smaller threshold values (negative thresholds such as -5 or -10 dB) indicate better than average hearing.

A person's audiometric threshold at a given test frequency is not an unchanging quantity. Measurement variability is associated with the state of the subject (including the subject's prior audiometric experience, attention, motivation, the influence of upper respiratory problems, drugs, and other factors) and with the testing equipment and methodology [Morrill 1986]. The higher the measurement variability, the more difficult it is to distinguish actual changes in hearing threshold.

Noise exposure increases hearing thresholds, resulting in threshold shifts toward higher values (poorer hearing). Occasionally, exposure to extremely intense noise may cause an immediate, permanent hearing loss known as acoustic trauma. Most often, exposure to less intense noise causes the gradual development of hearing damage over months and years. During each overexposure to noise the ear develops a temporary reduction in sensitivity called temporary threshold shift. This shift reverses over a period of hours or days if the ear is allowed to rest in a quieter environment. However, if the exposure is high enough or if exposures are repeated, the temporary threshold shift may not reverse completely, and a permanent threshold shift begins to develop.

Although the magnitude of the temporary threshold shift cannot be used to predict the magnitude of the permanent threshold shift, the former serves as a precursor to the latter.

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*Whenever the unit dB is used in audiometric testing, it actually refers to dB HTL.

NIOSH therefore suggests that monitoring audiometry be conducted on noise-exposed workers at the end of or late in their daily work shifts. Discovering and taking action to prevent further temporary threshold shift will result in more thorough worker protection from permanent hearing damage. If the annual monitoring audiometry is performed at the beginning of work shifts or before the workday begins, temporary threshold shifts that might have been present from the previous day's noise exposure will have been resolved—any threshold shifts observed will represent permanent shifts in hearing. This type of audiometric monitoring will serve only to document the development of permanent hearing loss, not to prevent it.

Some reports have indicated that industrial audiometry is too variable to be useful in detecting initial threshold shifts [Hétu 1979; Atherley and Johnston 1981]. Certainly, if testing procedures are too inconsistent, temporary or permanent threshold shifts may not be distinguishable from measurement variability. The challenge is to select a criterion for significant threshold shift that is stringent enough to detect incipient hearing loss, yet not so stringent as to identify large numbers of workers whose thresholds are simply showing normal variability. This challenge is compounded by the fact that the incipient permanent threshold shift may manifest itself with the same order of magnitude as typical audiometric measurement variability—about a 10-dB change in hearing thresholds. However, the daily temporary threshold shift is often larger in magnitude than the developing permanent threshold shift. So testing workers near the end of their work shifts (when temporary threshold shifts may be present) should increase the probability of identifying workers who are not adequately protected from noise.

In 1972, a significant threshold shift criterion was initially recommended by NIOSH [NIOSH 1972]. In 1992 and 1996, Royster [1992, 1996] examined the performance of this criterion against seven other criteria for significant threshold shift. The following threshold shift criteria were evaluated:

1. OSHA STS: in either ear, a change of 10 dB or more in the average of hearing thresholds at 2000, 3000, and 4000 Hz.

2. OSHA STS TWICE: in either ear, a change of 10 dB or more in the average of hearing thresholds at 2000, 3000, and 4000 Hz is present on one annual audiogram and is persistent in the same ear on the next audiogram.

3. American Academy of Otolaryngology—Head and Neck Surgery (AAO-HNS) SHIFT: in either ear, a change of 10 dB or more in the average of hearing thresholds at 500, 1000, and 2000 Hz, or 15 dB or more at 3000, 4000, and 6000 Hz.

4. 1972 NIOSH SHIFT: in either ear, a change of 10 dB or more at 500, 1000, 2000, or 3000 Hz, or 15 dB or more at 4000 or 6000 Hz.

5. 15-dB SHIFT: in either ear, a change of 15 dB or more at any test frequency from 500 through 6000 Hz.

6. 15-dB TWICE: in either ear, a change of 15 dB or more at any test frequency from 500 through 6000 Hz is present on one annual audiogram and is persistent at the same frequency in the same ear on the next audiogram.

7. 15-dB TWICE 1–4 kHz: in either ear, a change of 15 dB or more at any test frequency from 1000 through 4000 Hz is present on one annual audiogram and is persistent at the same frequency in the same ear on the next audiogram.

8. 10-dB AVG 3–4 kHz: in either ear, a change of 10 dB or more in the average of hearing thresholds at 3000 and 4000 Hz.

The study methodology, database characteristics, and results are described in detail in the Royster [1992, 1996] reports. This study compared each of the above eight criteria for threshold shifts by applying each criterion to 15 different industrial hearing conservation databases that were contributed to the ANSI S12 Working Group 12.

Within each database, analyses were restricted to the first eight audiograms for male workers who had at least eight tests. The numbers of workers included from each database ranged from 39 to 1,056. Data were analyzed for a total of 2,903 workers. For the purposes of these analyses, a "tag" was identified when a worker's audiogram (or two consecutive audiograms for the TWICE criteria) met a specified criterion, and a "true positive" was identified when the worker's audiogram showed the same threshold shift specified in that criterion.

A significant threshold shift for a worker, according to the four nonaveraging, any-frequency-shift criteria (1972 NIOSH SHIFT, 15-dB SHIFT, 15-dB TWICE, and 15-dB TWICE 1–4 kHz), was considered a true positive if the shift was confirmed by the succeeding audiogram—but only if the shift was persistent for at least one of the same frequencies in the same ear. For example, if a worker's Test 3 showed a 1972 NIOSH SHIFT at 2000, 4000, and 6000 Hz in the left ear, then the shift would be confirmed as a true positive if Test 4 showed the shift to be persistent in the same ear at one or more of the same frequencies. For three of the frequency-average criteria (OSHA STS, AAO-HNS SHIFT, and 10-dB AVG 3–4 kHz), a shift was considered a true positive if the worker's next audiogram showed a change by that same criterion, whether or not the confirming shift occurred in the same ear and/or the same frequency range (applicable to AAO-HNS). In other words, the original shift could be counted as confirmed not only by a persistent shift in the same ear at the same frequency average but also by a new shift in the other ear at any frequency average. For the OSHA STS TWICE criterion, a true positive was confirmed only by a persistent shift in the same ear on the next audiogram.

The data for classifying true positives from all 15 databases are presented in Table 5–1. The 15-dB TWICE and the 15-dB TWICE 1–4 kHz criteria yielded the two highest percentages of true positive tags—70.9% and 73.3%, respectively. The OSHA STS TWICE criterion yielded 57.0% true positive tags; the remaining criteria yielded between 40.4% and 46.1% true positive tags.

Table 5–1. Classifiable first tags* across 15 databases† and first tags classified as *true positive* for each of the 8-shift criteria‡

Criterion	Number of classifiable first tags	First tags classified as *true positive*	
		Number	%
OSHA STS	958	412	43.0
OSHA STS TWICE	356	203	57.0
AAO-HNS SHIFT	1,291	578	44.8
1972 NIOSH SHIFT	2,268	1,045	46.1
15-dB SHIFT	2,126	858	40.4
15-dB TWICE	1,056	749	70.9
15-dB TWICE 1–4 kHz	726	532	73.3
10-dB AVG. 3–4 kHz	1,175	524	44.6

*Those occurring in comparisons of Tests 2 through 7 back to Test 1.
†N=2,903.
‡Adapted from Royster [1992, 1996].

No criterion evaluated is best in every respect. The relative merits of each are tabulated in Table 5–2. An acceptable criterion should be able to identify promptly a worker with any measurable threshold shift at the most noise-sensitive audiometric frequencies and should tag a reasonably high number of true positives. Relative to the any-frequency criteria, those criteria that average thresholds at two or more audiometric frequencies (i.e., OSHA STS, OSHA STS TWICE, AAO-HNS SHIFT, and 10-dB AVG 3–4 kHz) yield lower numbers of tags with lower percentages of true positives.

For this analysis, the 15-dB TWICE and the 15-dB TWICE 1–4 kHz criteria require that a threshold shift persist on two tests before the worker is identified or "tagged" for meeting the criterion of significant threshold shift; these two criteria result in the two highest percentages of true positives. The 1972 NIOSH SHIFT, which shares with 15-dB TWICE the advantage of not requiring any frequency averaging, uses such a small amount of shift (only 10 dB) at 500 to 3000 Hz that it tags many audiograms that reflect normal testing variability. Thus the 1972 NIOSH SHIFT tags so many workers that it loses its usefulness as a problem identifier. This disadvantage can be partially overcome by increasing the amount of required shift to 15 dB (the 15-dB SHIFT); however, too many workers are still tagged by the 15-dB SHIFT to allow any meaningful followup.

The 15-dB TWICE 1–4 kHz criterion differs from the 15-dB TWICE criterion by excluding shifts at 500 and 6000 Hz. Hearing at the 500-Hz audiometric frequency is

Table 5–2. Advantages and disadvantages of each criterion for significant threshold shift*

Considerations	Criteria							
	OSHA STS	OSHA STS TWICE	AAO-HNS SHIFT	1972 NIOSH SHIFT	15-dB SHIFT	15-dB TWICE	15-dB TWICE 1–4 kHz	10-dB AVG. 3–4 kHz
	Advantages							
Tags a moderate % of workers			X			X		X
Gives high % of true positive tags						X	X	
Tags workers earliest				X				
No calculation of frequency averages required				X	X	X	X	
Averages noise-susceptible frequencies separately or examines each frequency separately			X	X	X	X	X	X
Includes all noise-susceptible frequencies			X	X	X	X		
	Disadvantages							
Tags a low % of workers	X	X					X	
Tags such a high % of workers that followup would be impractical				X	X			
Tags workers early in fewer cases		X				X	X	

*Adapted from Royster [1992, 1996].

(Continued)

Table 5–2 (Continued). Advantages and disadvantages of each criterion for significant threshold shift

Considerations	Criteria							
	OSHA STS	OSHA STS TWICE	AAO-HNS SHIFT	1972 NIOSH SHIFT	15-dB SHIFT	15-dB TWICE	15-dB TWICE 1–4 kHz	10-dB AVG. 3–4 kHz
	Disadvantages							
Requires calculations of frequency averages	X	X	X					X
Averages low frequencies that are unlikely to be affected by noise exposure			X					
Averages together frequencies that vary in susceptibility to noise	X	X						
Uses a shift magnitude within the range of normal audiometric variability				X				

unlikely to be affected by NIHL, but it may be useful as an indicator of excess ambient noise in the audiometric test booth and as an indicator of the presence of medical ear conditions such as conductive ear pathologies. The 6000-Hz audiometric frequency is one of the three high frequencies (3000, 4000, and 6000 Hz) at which hearing is most likely to be affected soonest and to the greatest degree by NIHL. This audiometric frequency is more susceptible than others to measurement variability if there is inconsistent earphone placement.

Excluding the 500- and 6000-Hz frequencies in the 15-dB TWICE 1–4 kHz criterion reduces the number of tags to less than that for ordinary OSHA STS; also, it does not increase the percentage of true positive tags by any practically important amount (2.4%). This indicates that the shifts at 500 Hz and 6000 Hz that meet the 15-dB TWICE criterion are reliable shifts, not spurious ones. Inclusion of the 6000-Hz frequency is desirable from the standpoint of identifying early NIHL. Therefore, the 15-dB TWICE criterion is preferable to the 15-dB TWICE 1-4 kHz criterion because it identifies a higher number of workers and provides a warning of noise-induced shifts at 6000 Hz, a noise-susceptible test frequency.

The ideal significant threshold shift criterion should tag workers with temporary threshold shifts before they develop into permanent hearing impairment. On the basis of the data analyses presented by Royster [1992, 1996], NIOSH now recommends a modified 15-dB TWICE, 500–6000 Hz criterion. NIOSH recommends an immediate retest after reinstruction and repositioning of the earphones if a 15-dB change in threshold is noted at any frequency. Rink [1989] observed the value of two back-to-back tests and reported that performing an immediate retest reduced the proportion of workers meeting the OSHA STS criterion by more than 70%. Thus, if a monitoring audiogram indicates a 15-dB shift or more in either ear at any one of the test frequencies (500, 1000, 2000, 3000, 4000, or 6000 Hz), the worker should be reinstructed, the earphones refitted, and the retest administered. If the retest shows the same results (i.e., a 15-dB shift or more in the same ear and at the same frequency), the 15-dB TWICE criterion for a significant threshold shift has been met, and the worker should be rescheduled for a confirmation test within 30 days. The confirmation audiogram shall be preceded by a 12-hr period with no exposure to workplace or other loud noises. Hearing protectors shall not be substituted in lieu of the required quiet period.

If the immediate retest is not performed, NIOSH recommends that the significant threshold shift be confirmed by a followup test within 30 days of the testing that showed the significant threshold shift. This followup test is called the confirmation test and is preceded by a 12-hr quiet period. If the significant threshold shift is confirmed and later validated by an audiologist or physician, the confirmation audiogram should be the one with which all subsequent audiograms are compared.

To comply with this recommendation and to provide maximum protection for workers and maximum documentation for employers, NIOSH advocates that audiograms be performed on the following occasions:

1. Before employment or before initial assignment into a hearing hazard work area.

2. Annually for any worker whose noise exposure equals or exceeds 85 dBA as an 8-hr TWA (monitoring audiometry). Annual testing may lead to a number of retests if a significant threshold shift occurs. In addition, it may be a good practice to provide audiometry twice per year to workers exposed to more than 100 dBA, because the most susceptible 10% of a population exposed to daily average noise levels of 100 dBA with inadequate hearing protectors could develop significant hearing loss well before the end of 1 year [NIOSH 1996].

3. At the time of reassignment from a job involving hearing hazards.

4. At the termination of employment.

5.5.1.1 Baseline Audiogram

The baseline audiogram should be obtained within 30 days of enrollment in the HLPP [NIOSH 1972]. It shall be preceded by a minimum of 12 hr of unprotected quiet. Data have supported the concept that following a period of noise exposure, the worker should be provided at least as much time for recovery from temporary threshold shifts as the duration of the noise exposure [Johnson et al. 1976]. Use of hearing protectors should not be considered a substitute for an actual 12-hr quiet period. Use of a mobile testing service should not waive these requirements. It is unacceptable to wait up to a year, as permitted by OSHA [29 CFR 1910.95], for a mobile service to conduct a baseline audiogram, because permanent hearing loss can occur within relatively short periods (months or even days in susceptible workers), especially when high levels of noise are involved [ISO 1990]. If a mobile service cannot meet these time constraints, other arrangements should be made to obtain the baseline audiograms before or promptly after employment.

5.5.1.2 Monitoring Audiograms

Monitoring audiometry shall be conducted no less than annually. Unlike baseline audiometry, these annual tests should be scheduled at the end of, or well into, the work shift so that temporary changes in hearing due to insufficient noise controls or inadequate use of hearing protection will be noted. The results should be compared immediately with the baseline audiogram to check for any change in hearing sensitivity. The collection of audiograms for later batch comparison with baseline audiograms in another location is an unacceptable practice because it does not afford the opportunity to conduct retests or to discuss the findings with workers in a timely manner.

5.5.1.3 Retest Audiograms

As good practice, NIOSH suggests that audiometry be repeated immediately after any monitoring audiogram that indicates a threshold shift of 15 dB or more at 500, 1000, 2000, 3000, 4000, or 6000 Hz in either ear. The worker should be reinstructed and the headphones refitted before conducting the retest. Those who employ the retest strategy

will find a significant reduction in the number of workers called back for a confirmation audiogram. The reason is that if the retest audiogram does not show the same shift as the monitoring audiogram, the retest audiogram becomes the test of record and there is no need to call the worker back for a confirmation audiogram.

5.5.1.4 Confirmation Audiograms

Audiometry should be conducted again within 30 days of any monitoring or retest audiogram that continues to show a significant threshold shift. A minimum of 12 hr of quiet shall precede the confirmation audiogram to determine whether the shift is a temporary or permanent change in hearing sensitivity (i.e., a temporary or permanent threshold shift). The use of hearing protectors as a substitute for a quiet environment is not acceptable. Confirmation audiograms indicating persistent threshold shifts shall trigger written notification to the worker and a referral to the audiometric manager for review and determination of probable etiology. This review should explore all possible causes in addition to occupational noise, including age-related hearing loss, familial hearing loss, medical history, nonoccupational noise exposure, etc. [Franks et al. 1989; Stepkin 1993]. Workers showing a threshold shift with a cause other than noise should be counseled by the audiometric manager and referred to their physicians for evaluation and treatment. Workers should also be referred if they meet any of the otologic or medical criteria recommended by AAO-HNS [1983]. Appropriate action should be triggered for workers showing a threshold shift that is determined by the audiometric manager to have occupational noise exposure as the probable cause. Actions shall, at a minimum, include reinstruction and refitting of hearing protectors, additional training in worker responsibilities for effective hearing loss prevention, and/or reassignment to quieter work areas. The audiometric manager should be responsible for making whatever recommendations he or she deems necessary and for seeing that they are carried out.

5.5.1.5 Exit Audiogram

Audiometry should be conducted when a worker leaves employment or is permanently rotated out of an occupational noise exposure at or above 85 dBA as an 8-hr TWA. This exit audiogram, like the baseline, should be performed after a minimum of 12 hr of quiet. The use of hearing protectors as a substitute for quiet is not acceptable.

NIOSH suggests that hearing tests be offered as a health benefit to workers who are not exposed to hazardous noise levels. The tests in these workers can be conducted early in the day—when it is not recommended that noise-exposed employees be tested for changes in hearing thresholds. In addition to providing a valuable internal control group for comparison to the noise-exposed workers, this policy elevates the perceived importance of the HLPP for management and workers [NIOSH 1996].

5.5.2 Audiometers

Audiometers shall, at a minimum, conform to the specifications of the appropriate ANSI standard for Type 4 audiometers [ANSI 1996b], with the additional stipulation that they

have the capacity for testing at 8000 Hz. Type 5 audiometers, which only test to 70 dB HTL, are unacceptable for threshold testing within an occupational HLPP.

Audiometers must be kept in calibration for the audiograms to have any value. An audiometer shall receive a functional check (sometimes called a biologic check) each day the instrument is used [Morrill 1986; NIOSH 1996]. This type of calibration check involves obtaining an audiogram from a person with known, stable thresholds and verifying that no changes in HTL exceeding 10 dB have occurred. A bioacoustic simulator check may be substituted for this procedure. In addition, the audiometer attenuator and frequency selection dials should be cycled through while carefully listening for any extraneous noise or distortion that might interfere with testing. The earphone cords should be manipulated to check for any unwanted static or noise. A check for unwanted sounds, such as the presence of the test signal in the nontest earphone, should be made in accordance with section 5.4.2 of ANSI S3.6–1996 *American National Standard Specification for Audiometers* [ANSI 1996b].

An acoustic calibration check shall be performed whenever the functional check indicates a threshold difference exceeding 10 dB in either earphone at any frequency. An acoustic calibration includes checks of output levels, attenuator linearity, and frequency. If the sound pressure levels differ by more than the allowable variances specified by ANSI S3.6–1996 [ANSI 1996b] (or its successor), or if the attenuator linearity differs by more than 1 dB, or if frequency drift exceeds 3%, an exhaustive calibration is necessary [Morrill 1986].

An exhaustive calibration check should be conducted annually or whenever an acoustic calibration indicates the need for such. An exhaustive calibration includes adjusting the audiometer so that it is in compliance with all specifications of ANSI S3.6–1996 [ANSI 1996b] (or its successor) and must be done by an audiometer service technician. It is best to have exhaustive calibrations performed onsite. If the audiometer must be shipped out for this service, an acoustic calibration shall be conducted upon its return to ensure that calibration changes did not occur during shipping [Morrill 1986].

The audiometric test area shall conform to the ambient noise requirements of ANSI S3.1–1991 [ANSI 1991b]. For permanent, onsite test areas, ambient noise levels shall be checked at least annually. For mobile test areas, ambient noise levels should be checked daily or at each new site, whichever is more frequent. Ambient noise levels should be checked with a calibrated sound level meter placed in the test environment at the approximate position that the worker's head will occupy during the test procedure. Some bioacoustic simulators have the capability of measuring ambient noise levels; this is acceptable provided that the unit is placed near the area of the worker's head. All audiometric test equipment as well as lights, heaters, air conditioners, etc. shall be set as they would be during actual testing. The ambient noise levels shall also be measured during audiometric testing; they should be recorded in a log through which they can be traced for each audiogram obtained.

5.6 Use of Hearing Protectors (Component 5)

NIOSH [1996] defines a hearing protector as "anything that can be worn to reduce the level of sound entering the ear." Hearing protectors are discussed more fully in Chapter 6; however, a few brief points should be made here. Hearing protectors are subject to many problems and should be considered the last resort against hazardous noise. Berger [1980] identified several reasons why hearing protectors can fail to provide adequate protection in real-world situations: discomfort, incorrect use with other safety equipment, dislodging, deterioration, and abuse. In addition, hearing protectors generally provide greatest protection from high frequency noise and significantly less protection from low-frequency noise [Berger 1986]. Nevertheless, hearing protectors *can* work as a short-term solution to prevent NIHL if their use is carefully planned, evaluated, and supervised [Berger 1986; Royster and Royster 1990; NIOSH 1996; Franks and Berger, in press].

5.7 Education and Motivation (Component 6)

On November 21, 1983, OSHA promulgated an occupational safety and health standard entitled "Hazard Communication" [29 CFR 1910.1200]. Under the provisions of this standard, employers in the manufacturing sector must establish a comprehensive hazard communication program that includes, at a minimum, container labeling, material safety data sheets, and a worker training program. The hazard communication program is to be written and made available to workers and their designated representatives. Although the Hazard Communication standard does not specifically address occupational noise exposure, the intent of the standard to inform workers of health hazards should apply. Annual training shall be provided to employees exposed to noise levels at or above 85 dBA as an 8-hr TWA. Workers must be informed of the possible consequences of noise exposure and of the various control methods available to protect their hearing. When an HLPP is implemented, workers should be informed of the provisions of the program and the benefits of their full participation in the program.

The success of an HLPP depends largely on effective worker education regarding all aspects of the program. In his review of the hearing conservation literature, Berger [1981] suggests several keys to a successful program: support from management, enforcement of safety policies, education and motivation of the workers, and comfortable and effective hearing protectors. All of these issues depend to some degree on a well-constructed, thorough program of educating and training everyone who is involved in the HLPP.

Obviously, the primary focus of the training component of the HLPP is on the workers. Workers need to be informed about the reasons for and the requirements of the HLPP at the time that they are enrolled. The education process should be ongoing and highlighted by periodic programs focusing on one or more particular aspects of the program. Furthermore, to be optimally effective, education should be tailored to the specific exposure and prevention needs of each worker or group of workers. Education and training will be easily dismissed unless it can be related to each worker's day-to-day functions

[Berger 1981]. Worker education should cover all relevant aspects of the hearing conservation program. At a minimum, the following topics should be included [AOMA 1987; Royster and Royster 1990; NIOSH 1996]:

1. *Requirements of and rationale for the occupational noise standard.*

2. *Effects of noise on hearing.* This should cover both the audiometric effects (i.e., how noise effects show up on an audiogram) and the functional effects (i.e., the impact of NIHL on everyday life).

3. *Company policy for the elimination of noise as a hazard, including noise controls already implemented or planned for the future.* This topic is very important and helps ensure that workers do not accidentally interfere with control measures.

4. *Hazardous noise sources at the worksite.* The discussion should include monitoring procedures, noise maps of the work environment, and use of warning signs as they apply at the site for the workers receiving training.

5. *Training in the use of hearing protectors.* This training should include (a) the purpose of hearing protectors, (b) the types of protectors available and the advantages and disadvantages of each, (c) selection, fitting, use, and care of hearing protectors, and (d) methods for solving common problems associated with hearing protector use. *This training must include supervised, hands-on practice in the proper fitting of hearing protectors.*

6. *Audiometry.* Instruction should include a discussion of the role of audiometry in preventing hearing loss, a description of the actual test procedure, and interpretation and implications of test results. It should be stressed that temporary or permanent threshold shifts indicate *failure* of the HLPP. Workers and managers need to know that threshold shifts may often be traced to inadequate protection resulting from ineffective noise controls and inconsistent use of hearing protectors.

7. *Individual responsibilities for preventing hearing loss.* A discussion of common nonoccupational noise sources and suggested ways of controlling these exposures will further increase the effectiveness of an occupational HLPP [Royster and Royster 1990]. In addition, behavioral research has suggested that it is important to encourage workers' feelings of self-efficacy, control, and personal responsibility for safety and health behavior [Schwarzer 1992].

Despite the emphasis on employee training, management also needs to be educated about the need for and elements of the HLPP. Strong management support is critical to an effective HLPP [AOMA 1987]. This support must be more than just implicit approval of company hearing loss prevention policies. It must be an outward, active show

of approval and compliance with the established policies. This support must be clearly evident to lower management, foremen, and workers. Management needs to know the basics of the legal and professional requirements for effective hearing loss prevention as well as the administrative requirements for compliance and the liability consequences of noncompliance. Motivation of upper management may be heightened by emphasizing the possible financial benefits of an effective HLPP on workers' compensation costs, improved productivity, and worker retention [Royster and Royster 1990].

In addition to the workers and managers, members of the hearing loss prevention team must be educated about company policy for the program and their role in it. They must receive appropriate training to enable them to fulfill their duties successfully. This training is *especially* important for those who will be responsible for fitting hearing protectors and training workers in their proper use [Royster and Royster 1990]. If a hierarchy of responsibility exists within the program's team, each member should know his or her place in it. Consultants, including physicians or audiologists who conduct followup examinations, should also be well informed about the company's hearing loss prevention policies to help prevent recommendations or decisions that might conflict with established company policy [Royster and Royster 1986].

Choice of educational and motivational strategies is critical to the success of the training phase of the HLPP. The techniques used and the content selected for presentation must be tailored to the particular needs of the audience [Royster and Royster 1990].

For all groups involved, an effective training program requires both episodic and ongoing educational opportunities. The most useful opportunity for episodic training of the workers occurs at the time of each worker's annual monitoring audiogram. During this time, the worker is most interested in his or her hearing status, and recommendations will have the most relevance. Time should be taken immediately after testing to explain the results of the hearing test, its relationship to the worker's baseline audiogram, and its implications for the adequacy of the worker's hearing protector use. Stable hearing should be praised to reinforce the worker's proper use of noise controls and hearing protectors, and hearing shifts should result in a sincere warning about the need for more *consistent* use of appropriate hearing protectors. The worker must be given the opportunity to ask questions about his or her role in the HLPP and should be encouraged to discuss hearing protector difficulties, etc. [Royster and Royster 1986].

Other opportunities for episodic training also exist. Special training sessions or regularly planned safety meetings should address company policies, results of biennial noise exposure monitoring, overviews of the effect of noise on hearing, and related topics. These training sessions should not be limited to showing a film but should be personally presented by an educator who is knowledgeable about hearing conservation and has an interesting presentation style. Group size should be small enough to permit interaction with the speaker and among the workers. Content should be varied and continually updated [Royster and Royster 1986; NIOSH 1996].

In addition to these episodic training sessions, an ongoing educational process should be offered. HLPP personnel, especially the program implementor, should visit the workers' jobsites to see how they are doing. They should talk to workers about the program when they meet them in the halls, at lunch, etc. Posters, bulletin boards, informational pamphlets, etc., can be used as a constant reminder of the importance that the company places on hearing conservation. Contests or awards for effective hearing conservation practices can be used to promote safe behavior [Royster and Royster 1986, 1990]; however, incentive programs should be planned and implemented with full worker participation or they may be perceived by the workers as manipulative attempts by management to control worker behavior [Merry 1995].

5.8 Recordkeeping (Component 7)

Recordkeeping involves creating and maintaining documents on each aspect of the HLPP. This documentation is more than just an exercise in paperwork or computer data entry. Recordkeeping provides the only compelling evidence that the HLPP components were properly, consistently, and thoroughly conducted. Program records are often needed many years after they are collected. If it cannot be established that they are valid, the records are useless. Clearly, documentation needs to be viewed as one of the most critical aspects of an HLPP [Gasaway 1985].

HLPP records are medical records and should be treated with the same degree of integrity and confidentiality. The recordkeeping system should be compatible with the company's general safety and health record system. The company should keep copies of all records, even if a contractor collects the data [NIOSH 1996]. In addition, each worker's noise exposure records, audiometric records, hearing protection records, and training participation records should be cross-referenced so that information about one program component can be readily linked with information about all other program components for that worker. Such cross-referencing is critical to building a total hearing history and establishing the probable cause of any hearing loss should a claim ever be filed [Gasaway 1985; NIOSH 1996].

5.8.1 Noise Exposure Records

Noise exposure records need to include the worker's name, identification number, job code, job description, department, and similar related information such as the current noise exposure level, the date of the last exposure assessment, the monitoring method used, and the name of the person who did the monitoring [NIOSH 1996]. The employee's record should also include the previous noise exposure history. It is useful to include both calculated exposure levels and the raw data from which the calculations were made [Royster et al. 1986].

Noise exposure records should be maintained for a minimum of 30 years, the period that OSHA requires employers to keep other industrial hygiene records [29 CFR 1910.20]. However, it may be prudent to keep noise exposure records even longer. Royster et al.

[1986] recommend that exposure records be maintained for the length of employment plus 30 years. Employers might also consult their State workers' compensation agencies. Most States have a statute of limitations for filing a claim for occupational hearing loss; however, some States do not [ASHA 1992]. Prudence dictates a check with State regulations to be certain that records are maintained until it is determined that there will be no further use for them [Royster et al. 1986].

5.8.2 Audiometric Records

Audiometric records need to include the worker's name, identification number, sex, date of birth, and a self-reported worker history. The history should include medical information that may have an impact on hearing status, history of past occupational or military noise exposure, and types of nonoccupational noise exposure [Helmkamp et al. 1984; NIOSH 1996]. Occupational exposure to potentially ototoxic chemicals should also be recorded [Rybak 1992]. Morrill recommends a brief "high-risk" history, which can be readily taken by a technician; this history can then be used as a framework for a more detailed history, as necessary, if the worker is ever referred to an audiologist or physician for further evaluation [Morrill 1986]. The more detailed the history, the more accurately the audiometric manager will be able to determine the actual cause of any threshold shifts.

For each audiometric examination, the test date, time, and hours since the worker's last noise exposure shall be recorded. Audiometric thresholds at all required frequencies should be recorded. The audiometer's make, model, and serial number shall be noted, as well as the dates of the last exhaustive calibration, the last acoustic calibration, the last functional check, and the last check of room ambient noise levels. In addition, the identity of the tester and the tester's subjective assessment of test reliability should be recorded [NIOSH 1996].

Any time a significant threshold shift is documented, the cause determined by the audiometric manager should be recorded. Also, all followup actions should be documented [Gasaway 1985].

Audiometric test results and records of causes of any confirmed shifts should be maintained for the duration of employment plus 30 years, which is the OSHA requirement for worker health records [29 CFR 1910.20]. Other supporting records (e.g., calibration records, ambient noise level checks, etc.) should be maintained for at least 5 years. However, bearing in mind that audiometric records are only as valid as documentation indicates, it may be prudent to keep all supporting records for as long as the thresholds themselves are maintained [Gasaway 1985].

5.8.3 Hearing Protection Records

Hearing protection records should include the types of hearing protectors used, including make, model, and size, as relevant. Records should also be maintained to document

training received by the workers in the proper fitting and use of protectors and the consistency of compliance with requirements for wearing hearing protectors [NIOSH 1996]. Hearing protection records should be maintained for a minimum of 30 years; however, each worker's history of hearing protector use should be kept with the audiograms that are maintained for the duration of employment plus 30 years.

5.8.4 Education Records

Education records should include date and type of training provided, who conducted the training, and attendance (if training was a group program) [NIOSH 1996]. Each worker's education and training records should also be maintained for the duration of employment plus 30 years.

5.8.5 Other Records

Other necessary records might include documentation of periodic audits, exposure assessments, plans for engineering and administrative controls, and results of overall program evaluations [NIOSH 1996]. These records and any other documentation relevant to the HLPP should be maintained for a minimum of 30 years.

5.9 Evaluation of Program Effectiveness (Component 8)

The effectiveness of an HLPP should be evaluated in terms of the hearing losses prevented for each worker and the overall rate of hearing loss in the population of workers. This evaluation should occur on a continual basis.

5.9.1 Individual Effectiveness

The effectiveness of the HLPP in preserving workers' hearing is best evaluated through audiometric monitoring of each noise-exposed worker. All workers whose time-weighted noise exposure meets or exceeds 85 dBA shall receive audiometric testing at no cost to the worker at the intervals noted previously under audiometric evaluation. Comparison of a current audiogram with the baseline audiogram will permit the audiometric manager to assess the adequacy of the program elements for that particular worker. Thus each audiogram serves as a marker of the effectiveness of the hearing loss prevention effort for that individual worker. Any apparent changes in hearing indicate a possible failure in the program.

5.9.2 Overall Program Effectiveness

To assess the effectiveness of the HLPP from an overall programmatic level, it is necessary to have an evaluation method that can monitor trends in the population of workers enrolled in the program and thus identify program problems before many individual threshold shifts occur. This evaluation has two parts. The first part evaluates the internal

integrity of the audiometric data. A draft ANSI standard currently details a method for such an evaluation—Draft ANSI S12.13–1991, *American National Standard Evaluating the Effectiveness of Hearing Conservation Programs* [ANSI 1991c]. This standard is based on an assumption that year-to-year variability in a population's hearing thresholds reflects the adequacy of the audiometric monitoring program. High variability in sequential thresholds indicates inadequate control of audiometric test procedures, audiometric calibration problems, or poor recordkeeping. Low variability in sequential thresholds indicates a well-controlled program producing results that may be relied on for accuracy and reliability.

The second part of the program evaluation involves comparing the rate of threshold shift among noise-exposed workers to that of persons not exposed to occupational noise. To this end, Melnick [1984] evaluated the efficacy of several methods. The first was based on the OSHA estimation that a noise-exposed population in compliance with the current noise regulations would still demonstrate a prevalence of hearing loss (defined as thresholds exceeding 25 dB at the frequencies of 500, 1000, and 2000 Hz) up to 10% greater than a non-noise-exposed population by the time workers reached retirement (later OSHA calculations have revised this estimate to be 10% to 15%). This method has the obvious disadvantage of delaying evaluation of the HLPP until a number of workers have reached retirement age; by then, however, improvements to the HLPP will be too late to prevent their hearing loss.

Another method involves evaluating the effectiveness of the overall program on the basis of the percentage of workers showing significant threshold shifts. Ideally, this criterion could be based on a control group (i.e., non-noise-exposed) *within the same company*. However, this system requires that *all* workers, whether or not they are noise-exposed, receive annual audiometric evaluations. Others who have investigated the possibility of using the percentage of significant threshold shifts as an evaluation criterion have reported that 3% to 6% [Morrill and Sterrett 1981] or 5% significant threshold shifts [Franks et al. 1989; Simpson et al. 1994] are reasonable incidence rates that can be met by effective programs. Significant threshold shift incidence rates exceeding these percentages might then be considered evidence of a deficient program. One disadvantage of this technique is that it does not account for the effects of other variables (e.g., age, sex, race, and previous noise exposure history) that might affect the significant threshold shift incidence rates if the noise and nonnoise populations differ substantially. Another disadvantage is that this technique does not differentiate possible causes of program deficiencies. Problems could be as likely to be due to poor audiometry as to excessive noise exposure [Melnick 1984; Simpson et al. 1994].

Pell [1972] used an alternative method in evaluating the effectiveness of the hearing conservation program at DuPont. This method involves a longitudinal analysis of the rate of increased hearing loss (10th, 50th, and 90th percentiles) as a function of age for three classes of worker noise exposure: quiet (<85 dBA), low noise (85–94 dBA), and high noise (>94 dBA). Pell [1972] judged his hearing conservation program to be effective by demonstrating that the rate of hearing loss increase with respect to age did not significantly differ among the three noise categories. This system also requires that both

noise-exposed and nonexposed workers receive annual audiometric evaluations. Also, because some persons are susceptible to hearing loss at the REL of 85 dBA, it would be preferable to define the quiet group as those exposed to less than 80 dBA.

The U.S. Army Center for Health Promotion and Preventive Medicine (formerly the U.S. Army Environmental Hygiene Agency) evaluates its HLPPs by rating each element and subelement of the program on a five-point scale ranging from maximally compliant to noncompliant. Total points are added across the subelements to achieve a score for that program element; then a total score is computed for the overall program. Well-defined criteria exist for scoring the subelements, but the program evaluator is also given some flexibility in assigning ratings. Such a system is helpful in that it defines strict criteria for every aspect of the program; these must be met to have a fully successful program. However, some of the currently used criteria are not perfect, because the Center has found several highly rated HLPPs to have unacceptably high incidences of significant threshold shifts [Byrne and Monk 1993].

In general, NIOSH suggests that the success of a smaller HLPP be judged by the audiometric results of individual workers. If there is zero tolerance for occupational hearing loss and a commitment to discover the cause of every change in hearing for each person in the HLPP, the overall program effectiveness should be assured. When it is not possible to examine each worker's results to obtain an adequate picture of the program's efficacy (e.g., if records are inaccessible), an overall evaluation criterion is necessary. Currently, no single method is generally accepted for the overall evaluation of HLPPs. Furthermore, no single method stands out as being superior to the rest. Although previous studies have recommended an incidence rate of significant threshold shift of 5% or less as evidence of an effective HLPP [Morrill and Sterrett 1981; Franks et al. 1989; Simpson et al. 1994], NIOSH currently recommends an incidence rate of 3% or less. The 3% rate is calculated by using the data from a population not exposed to occupational noise in Annex C of ANSI S3.44–1996, *American National Standard Determination of Occupational Noise Exposure and Estimation of Noise-Induced Hearing Impairment* [ANSI 1996c]. In the future, it may be preferable to use incidence rates based on the data from the upcoming National Health and Nutrition Examination Survey (NHANES) IV. These data will reflect the hearing of nonoccupational-noise-exposed cohorts that are contemporary to the present workforce enrolled in HLPPs. They will allow consideration of the effects of age, sex, race, and previous exposures to occupational and nonoccupational noises.

5.10 Age Correction

NIOSH does not recommend that age correction be applied to an individual's audiogram for significant threshold shift calculations. Although many people experience some decrease in hearing sensitivity with age, some do not. It is not possible to know who will and who will not have an age-related hearing loss. Thus, applying age corrections to a person's hearing thresholds for calculation of significant threshold shift will overestimate the expected hearing loss for some and underestimate it for others, because

the median hearing loss attributable to presbycusis for a given age group will not be generalizable to that experienced by an individual in that age group. The data on age-related hearing losses describe only the statistical distributions in populations. Furthermore, the age-correction tables developed in the 1972 criteria document [NIOSH 1972] (and subsequently included in the 1983 OSHA Hearing Conservation Amendment to the Occupational Noise Standard [48 Fed. Reg. 9738 (1983)]) were based on a cross-sectional study. Longitudinal data were not available, and the age corrections were estimated by calculating trends as a function of the age of each member of the sample. When data from a cross-sectional study are used, the inherent assumption is that a subject who was 20 years old in 1970 can be expected to experience the same age-related hearing loss by the year 2000 that a 50-year-old subject experienced in 1970. This assumption may not be valid because the general health and societal noise exposures of each generation are likely to differ.

The adjustment of audiometric thresholds for aging has become a common practice in workers' compensation litigation. In this application, age corrections reduce the amount of hearing loss attributable to noise exposure, with a consequent reduction in the amount of compensation paid to workers for their hearing losses. However common "age correcting" is and regardless of the extent to which it is applied, it is technically inappropriate to apply population statistics to an individual. Each age correction number is nothing more than a median value from a population distribution. In age-correcting an audiogram, the underlying assumption is that the individual value is given the 50th percentile, when in fact the 10th or 90th percentile may be the correct value. Thus age-correction formulas cannot be applied to determine with certainty how much of an individual's hearing loss is due to age and how much is due to noise exposure.

Age-correcting audiograms obtained as part of an occupational HLPP are even less appropriate. This is not a compensation issue. The purpose of the program is to prevent hearing loss. If an audiogram is age corrected, regardless of the source of the correction values, the time required for a significant threshold shift to be noted will be prolonged. Delaying the identification of a worker with a significant threshold shift is completely contrary to the purpose of an HLPP.