CRITERIA FOR A RECOMMENDED STANDARD

Occupational Noise Exposure

Revised Criteria 1998

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FOREWORD

In the Occupational Safety and Health Act of 1970 (Public Law 91-596), Congress declared that its purpose was to assure, so far as possible, safe and healthful working conditions for every working man and woman and to preserve our human resources. In this Act, the National Institute for Occupational Safety and Health (NIOSH) is charged with recommending occupational safety and health standards and describing exposure concentrations that are safe for various periods of employment—including but not limited to concentrations at which no worker will suffer diminished health, functional capacity, or life expectancy as a result of his or her work experience. By means of criteria documents, NIOSH communicates these recommended standards to regulatory agencies (including the Occupational Safety and Health Administration [OSHA]) and to others in the occupational safety and health community.

Criteria documents provide the scientific basis for new occupational safety and health standards. These documents generally contain a critical review of the scientific and technical information available on the prevalence of hazards, the existence of safety and health risks, and the adequacy of control methods. In addition to transmitting these documents to the Department of Labor, NIOSH also distributes them to health professionals in academic institutions, industry, organized labor, public interest groups, and other government agencies.

In 1972, NIOSH published *Criteria for a Recommended Standard: Occupational Exposure to Noise*, which provided the basis for a recommended standard to reduce the risk of developing permanent hearing loss as a result of occupational noise exposure [NIOSH 1972]. NIOSH has now evaluated the latest scientific information and has revised some of its previous recommendations. The 1998 recommendations go beyond attempting to conserve hearing by focusing on preventing occupational noise-induced hearing loss (NIHL).

The NIOSH recommended exposure limit (REL) for occupational noise exposure (85 decibels, A-weighted, as an 8-hour time-weighted average [85 dBA as an 8-hr TWA]) was reevaluated using contemporary risk assessment techniques and incorporating the 4000-hertz (Hz) audiometric frequency in the definition of hearing impairment. The new risk assessment reaffirms support for the 85-dBA REL. With a 40-year lifetime exposure at the 85-dBA REL, the excess risk of developing occupational NIHL is 8%—considerably lower than the 25% excess risk at the 90-dBA permissible exposure limit (PEL) currently enforced by the Occupational Safety and Health Administration (OSHA) and the Mine Safety and Health Administration (MSHA).

NIOSH previously recommended an exchange rate of 5 dB for the calculation of time-weighted average (TWA) exposures to noise. However, NIOSH now recommends a 3-dB exchange rate, which is more firmly supported by scientific evidence. The 5-dB exchange rate is still used by OSHA and MSHA, but the 3-dB exchange rate has been increasingly supported by national and international consensus.

NIOSH recommends an improved criterion for significant threshold shift: an increase of 15 dB in the hearing threshold level (HTL) at 500, 1000, 2000, 3000, 4000, or 6000 Hz in either ear, as determined by two consecutive audiometric tests. The new criterion has the advantages of a high identification rate and a low false-positive rate. In comparison, the criterion NIOSH recommended in 1972 has a high false-positive rate, and the OSHA criterion (called the standard threshold shift) has a relatively low identification rate.

In contrast with the 1972 criterion, the new NIOSH criterion no longer recommends age correction on individual audiograms. This practice is not scientifically valid and would delay intervention to prevent further hearing losses in workers whose HTLs have increased because of occupational noise exposure. OSHA currently allows age correction only as an option.

The noise reduction rating (NRR) is a single-number, laboratory-derived rating that the U.S. Environmental Protection Agency (EPA) requires to be shown on the label of each hearing protector sold in the United States. In calculating the noise exposure to the wearer of a hearing protector at work, OSHA derates the NRR by one-half for all types of hearing protectors. In 1972, NIOSH recommended the use of the full NRR value; however, in this document, NIOSH recommends derating by subtracting from the NRR 25%, 50%, and 70% for earmuffs, formable earplugs, and all other earplugs, respectively. This variable derating scheme, as opposed to OSHA's straight derating scheme, considers the performances of different types of hearing protectors.

This document also provides recommendations for the management of hearing loss prevention programs (HLPPs) for workers whose noise exposures equal or exceed 85 dBA. The recommendations include program evaluation, which was not articulated in the 1972 criteria document and is not included in the OSHA and MSHA standards.

Adherence to the revised recommended noise standard will minimize the risk of developing occupational NIHL.

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ABSTRACT

This criteria document reevaluates and reaffirms the recommended exposure limit (REL) for occupational noise exposure established by the National Institute for Occupational Safety and Health (NIOSH) in 1972. The REL is 85 decibels, A-weighted, as an 8-hr time-weighted average (85 dBA as an 8-hr TWA). Exposures at or above this level are hazardous.

By incorporating the 4000-Hz audiometric frequency into the definition of hearing impairment in the risk assessment, NIOSH has found an 8% excess risk of developing occupational noise-induced hearing loss (NIHL) during a 40-year lifetime exposure at the 85-dBA REL. NIOSH has also found that scientific evidence supports the use of a 3-dB exchange rate for the calculation of TWA exposures to noise.

The recommendations in this document go beyond attempts to conserve hearing by focusing on prevention of occupational NIHL. For workers whose noise exposures equal or exceed 85 dBA, NIOSH recommends a hearing loss prevention program (HLPP) that includes exposure assessment, engineering and administrative controls, proper use of hearing protectors, audiometric evaluation, education and motivation, recordkeeping, and program audits and evaluations.

Audiometric evaluation is an important component of an HLPP. To provide early identification of workers with increasing hearing loss, NIOSH has revised the criterion for significant threshold shift to an increase of 15 dB in the hearing threshold level (HTL) at 500, 1000, 2000, 3000, 4000, or 6000 Hz in either ear, as determined by two consecutive tests. To permit timely intervention and prevent further hearing losses in workers whose HTLs have increased because of occupational noise exposure, NIOSH no longer recommends age correction on individual audiograms.

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ABBREVIATIONS

AAO-HNS	American Academy of Otolaryngology-Head and Neck Surgery
AIHA	American Industrial Hygiene Association
ANSI	American National Standards Institute
AOMA	American Occupational Medical Association
ASHA	American Speech-Language-Hearing Association
CAOHC	Council for Accreditation in Occupational Hearing Conservation
CFR	*Code of Federal Regulations*
CHABA	Committee on Hearing, Bioacoustics, and Biomechanics
CI	confidence interval
dB	decibel(s)
dB SPL	decibel(s), sound pressure level
dBA	decibel(s), A-weighted
EPA	U.S. Environmental Protection Agency
Fed. Reg.	*Federal Register*
HLPP	hearing loss prevention program
hr	hour(s)
HTL	hearing threshold level
Hz	hertz
ISO	International Standards Organization
kHz	kilohertz
$L_{Aeq\,8\,hr}$	equivalent continuous sound for 8 hr
min	minute(s)

ms	millisecond(s)
MSHA	Mine Safety and Health Administration
NHANES	National Health and Nutrition Examination Survey
NHCA	National Hearing Conservation Association
NIHL	noise-induced hearing loss
NIOSH	National Institute for Occupational Safety and Health
NOES	National Occupational Exposure Survey
NOHSM	National Occupational Health Survey of Mining
NRR	noise reduction rating
ONHS	Occupational Noise and Hearing Survey
OSHA	Occupational Safety and Health Administration
PEL	permissible exposure limit
REAT	real ear attenuation at threshold
REL	recommended exposure limit
s	second(s)
SIC	standard industrial classification
SPL	sound pressure level
STS	standard threshold shift
T-BEAM	task-based exposure assessment model
TTS_2	temporary threshold shift 2 min after a period of noise exposure
TWA	time-weighted average

GLOSSARY

Where possible, the definition is quoted from the appropriate American National Standards Institute (ANSI) standard, ANSI S1.1–1994 [ANSI 1994] or ANSI S3.20–1995 [ANSI 1995], under the term(s) used in that standard.

Audiogram: Graph of hearing threshold level as a function of frequency (ANSI S3.20–1995: audiogram).

Baseline audiogram: The audiogram obtained from an audiometric examination administered before employment or within the first 30 days of employment that is preceded by a period of at least 12 hr of quiet. The baseline audiogram is the audiogram against which subsequent audiograms will be compared for the calculation of significant threshold shift.

Continuous noise: Noise with negligibly small fluctuations of level within the period of observation (ANSI S3.20–1995: stationary noise; steady noise).

Crest factor: Ten times the logarithm to the base ten of the square of the wideband peak amplitude of a signal to the time-mean-square amplitude over a stated time period. Unit, dB (ANSI S3.20–1995: crest factor).

Decibel (dB): Unit of level when the base of the logarithm is the 10th root of 10 and the quantities concerned are proportional to power (ANSI S1.1–1994: decibel).

Decibel, A-weighted (dBA): Unit representing the sound level measured with the A-weighting network on a sound level meter. (Refer to Table 4–1 for the characteristics of the weighting networks.)

Decibel, C-weighted (dBC): Unit representing the sound level measured with the C-weighting network on a sound level meter. (Refer to Table 4–1 for the characteristics of the weighting networks.)

Derate: To use a fraction of a hearing protector's noise reduction rating (NRR) to calculate the noise exposure of a worker wearing that hearing protector. (See NRR below.)

Dose: The amount of actual exposure relative to the amount of allowable exposure, and for which 100% and above represents exposures that are hazardous. The noise dose is calculated according to the following formula:

$$D = [C_1/T_1 + C_2/T_2 + \ldots + C_n/T_n] \times 100$$

Where

C_n = total time of exposure at a specified noise level
T_n = exposure time at which noise for this level becomes hazardous

Effective noise level: The estimated A-weighted noise level at the ear when wearing hearing protectors. Effective noise level is computed by (1) subtracting derated NRRs from C-weighted noise exposure levels, or (2) subtracting derated NRRs minus 7 dB from A-weighted noise exposure levels. Unit, dB. (See Appendix.)

Equal-energy hypothesis: A hypothesis stating that equal amounts of sound energy will produce equal amounts of hearing impairment, regardless of how the sound energy is distributed in time.

Equivalent continuous sound level: Ten times the logarithm to the base ten of the ratio of time-mean-square instantaneous A-weighted sound pressure, during a stated time interval T, to the square of the standard reference sound pressure. Unit, dB; respective abbreviations, TAV and TEQ; respective letter symbols, L_{AT} and L_{AeqT} (ANSI S1.1–1994: time-average sound level; time-interval equivalent continuous sound level; time-interval equivalent continuous A-weighted sound pressure level; equivalent continuous sound level).

Excess risk: Percentage with material impairment of hearing in an occupational-noise-exposed population after subtracting the percentage who would normally incur such impairment from other causes in a population not exposed to occupational noise.

Exchange rate: An increment of decibels that requires the halving of exposure time, or a decrement of decibels that requires the doubling of exposure time. For example, a 3-dB exchange rate requires that noise exposure time be halved for each 3-dB increase in noise level; likewise, a 5-dB exchange rate requires that exposure time be halved for each 5-dB increase.

Fence: The hearing threshold level above which a material impairment of hearing is considered to have occurred.

Frequency: For a function periodic in time, the reciprocal of the period. Unit, hertz (Hz) (ANSI S1.1–1994: frequency).

Hearing threshold level (HTL): For a specified signal, amount in decibels by which the hearing threshold for a listener, for one or both ears, exceeds a specified reference equivalent threshold level. Unit, dB (ANSI S1.1–1994: hearing level; hearing threshold level).

Immission level: A descriptor for noise exposure, in decibels, representing the total sound energy incident on the ear over a specified period of time (e.g., months, years).

Impact: Single collision of one mass in motion with a second mass that may be in motion or at rest (ANSI S1.1–1994: impact).

Impulse: Product of a force and the time during which the force is applied; more specifically, impulse is the time integral of force from an initial time to a final time, the force being

time-dependent and equal to zero before the initial time and after the final time (ANSI S1.1–1994: impulse).

Impulsive noise: Impulsive noise is characterized by a sharp rise and rapid decay in sound levels and is less than 1 sec in duration. For the purposes of this document, it refers to impact or impulse noise.

Intermittent noise: Noise levels that are interrupted by intervals of relatively low sound levels.

Noise: (1) Undesired sound. By extension, noise is any unwarranted disturbance within a useful frequency band, such as undesired electric waves in a transmission channel or device. (2) Erratic, intermittent, or statistically random oscillation (ANSI S1.1–1994: noise).

Noise reduction rating (NRR): The NRR, which indicates a hearing protector's noise reduction capabilities, is a single-number rating that is required by law to be shown on the label of each hearing protector sold in the United States. Unit, dB.

Permanent threshold shift (PTS): Permanent increase in the threshold of audibility for an ear. Unit, dB (ANSI S3.20–1995: permanent threshold shift; permanent hearing loss; PTS).

Pulse range: Difference in decibels between the peak level of an impulsive signal and the root-mean-square level of a continuous noise.

Significant threshold shift: A shift in hearing threshold, outside the range of audiometric testing variability (±5 dB), that warrants followup action to prevent further hearing loss. NIOSH defines significant threshold shift as an increase in the HTL of 15 dB or more at any frequency (500, 1000, 2000, 3000, 4000, or 6000 Hz) in either ear that is confirmed for the same ear and frequency by a second test within 30 days of the first test.

Sound: (1) Oscillation in pressure, stress, particle displacement, particle velocity, etc. in a medium with internal forces (e.g., elastic or viscous), or the superposition of such propagated oscillations. (2) Auditory sensation evoked by the oscillation described above (ANSI S1.1–1994: sound).

Sound intensity: Average rate of sound energy transmitted in a specified direction at a point through a unit area normal to this direction at the point considered. Unit, watt per square meter (W/m^2); symbol, I (ANSI S1.1–1994: sound intensity; sound-energy flux density; sound-power density).

Sound intensity level: Ten times the logarithm to the base ten of the ratio of the intensity of a given sound in a stated direction to the reference sound intensity of 1 picoWatt per square meter (pW/m^2). Unit, dB; symbol, L (ANSI S1.1–1994: sound intensity level).

Sound pressure: Root-mean-square instantaneous sound pressure at a point during a given time interval. Unit, Pascal (Pa) (ANSI S1.1–1994: sound pressure; effective sound pressure).

Sound pressure level: (1) Ten times the logarithm to the base ten of the ratio of the time-mean-square pressure of a sound, in a stated frequency band, to the square of the reference sound pressure in gases of 20 micropascals (μPa). Unit, dB; symbol, L_p. (2) For sound in media other than gases, unless otherwise specified, reference sound pressure in 1 μPa (ANSI S1.1–1994: sound pressure level).

Temporary threshold shift: Temporary increase in the threshold of audibility for an ear caused by exposure to high-intensity acoustic stimuli. Such a shift may be caused by other means such as use of aspirin or other drugs. Unit, dB. (ANSI S3.20–1995: temporary threshold shift; temporary hearing loss).

Time-weighted average (TWA): The averaging of different exposure levels during an exposure period. For noise, given an 85-dBA exposure limit and a 3-dB exchange rate, the TWA is calculated according to the following formula:

$$\text{TWA} = 10.0 \times \text{Log}(D/100) + 85$$

where D = dose.

Varying noise: Noise, with or without audible tones, for which the level varies substantially during the period of observation (ANSI S3.20–1995: nonstationary noise; nonsteady noise; time-varying noise).

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CHAPTER 1

Recommendations for a Noise Standard

The National Institute for Occupational Safety and Health (NIOSH) recommends the following standard for promulgation by regulatory agencies such as the Occupational Safety and Health Administration (OSHA) and the Mine Safety and Health Administration (MSHA) to protect workers from hearing losses resulting from occupational noise exposure. If this recommended standard is promulgated by a regulatory agency, the mandatory and nonmandatory provisions of the standard are indicated by the words *shall* and *should*, respectively.

1.1 Recommended Exposure Limit (REL)

The NIOSH recommended exposure limit (REL) for occupational noise exposure encompasses the provisions in Sections 1.1.1 through 1.1.4. The REL is 85 decibels, A-weighted, as an 8-hr time-weighted average (85 dBA as an 8-hr TWA). Exposures at and above this level are considered hazardous.

1.1.1 Exposure Levels and Durations

Occupational noise exposure shall be controlled so that worker exposures are less than the combination of exposure level (L) and duration (T), as calculated by the following formula (or as shown in Table 1–1).

$$T\,(\text{min}) = \frac{480}{2^{(L-85)/3}}$$

where 3 = the exchange rate.

1.1.2 Time-Weighted Average (TWA)

In accordance with Section 1.1.1, the REL for an 8-hr work shift is a TWA of 85 dBA using a 3-decibel (dB) exchange rate.

1.1.3 Daily Noise Dose

When the daily noise exposure consists of periods of different noise levels, the daily dose (D) shall not equal or exceed 100, as calculated according to the following formula:

$$D = [C_1/T_1 + C_2/T_2 + ... + C_n/T_n] \times 100$$

where

C_n = total time of exposure at a specified noise level, and
T_n = exposure duration for which noise at this level becomes hazardous.

The daily dose can be converted into an 8-hr TWA according to the following formula (or as shown in Table 1–2):

$$\text{TWA} = 10.0 \times \text{Log}(D/100) + 85$$

Table 1–1. Combinations of noise exposure levels and durations that no worker exposure shall equal or exceed

Exposure level, *L* (dBA)	Duration, *T*			Exposure level, *L* (dBA)	Duration, *T*		
	Hours	Minutes	Seconds		Hours	Minutes	Seconds
80	25	24	—	106	—	3	45
81	20	10	—	107	—	2	59
82	16	—	—	108	—	2	22
83	12	42	—	109	—	1	53
84	10	5	—	110	—	1	29
85	8	—	—	111	—	1	11
86	6	21	—	112	—	—	56
87	5	2	—	113	—	—	45
88	4	—	—	114	—	—	35
89	3	10	—	115	—	—	28
90	2	31	—	116	—	—	22
91	2	—	—	117	—	—	18
92	1	35	—	118	—	—	14
93	1	16	—	119	—	—	11
94	1	—	—	120	—	—	9
95	—	47	37	121	—	—	7
96	—	37	48	122	—	—	6
97	—	30	—	123	—	—	4
98	—	23	49	124	—	—	3
99	—	18	59	125	—	—	3
100	—	15	—	126	—	—	2
101	—	11	54	127	—	—	1
102	—	9	27	128	—	—	1
103	—	7	30	129	—	—	1
104	—	5	57	130–140	—	—	<1
105	—	4	43	—	—	—	—

Table 1–2. Daily noise dose as an 8-hr TWA*

Dose (%)	dBA as 8-hr TWA	Dose (%)	dBA as 8-hr TWA	Dose (%)	dBA as 8-hr TWA
20	78.0	2,000	98.0	450,000	121.5
30	79.8	2,500	99.0	500,000	122.0
40	81.0	3,000	99.8	600,000	122.8
50	82.0	3,500	100.4	700,000	123.5
60	82.8	4,000	101.0	800,000	124.0
70	83.5	4,500	101.5	900,000	124.5
80	84.0	5,000	102.0	1,000,000	125.0
90	84.5	6,000	102.8	1,100,000	125.4
100	85.0	7,000	103.5	1,200,000	125.8
110	85.4	8,000	104.0	1,300,000	126.1
120	85.8	9,000	104.5	1,400,000	126.5
130	86.1	10,000	105.0	1,600,000	127.0
140	86.5	12,000	105.8	1,800,000	127.6
150	86.8	14,000	106.5	2,000,000	128.0
170	87.3	16,000	107.0	2,200,000	128.4
200	88.0	18,000	107.6	2,400,000	128.8
250	89.0	20,000	108.0	2,600,000	129.1
300	89.8	25,000	109.0	2,800,000	129.5
350	90.4	30,000	109.8	3,000,000	129.8
400	91.0	35,000	110.4	3,500,000	130.4
450	91.5	40,000	111.0	4,000,000	131.0
500	92.0	45,000	111.5	4,500,000	131.5
550	92.4	50,000	102.0	5,000,000	132.0
600	92.8	60,000	112.8	6,000,000	132.8
650	93.1	70,000	113.5	7,000,000	133.5
700	93.5	80,000	114.0	8,000,000	134.0
750	93.8	90,000	114.5	9,000,000	134.5
800	94.0	100,000	115.0	10,000,000	135.0
900	94.5	110,000	115.4	12,000,000	135.8
1,000	95.0	120,000	115.8	14,000,000	136.5
1,050	95.2	130,000	116.1	16,000,000	137.0
1,100	95.4	140,000	116.5	18,000,000	137.6
1,150	95.6	150,000	116.8	20,000,000	138.0
1,200	95.8	175,000	117.4	22,000,000	138.4
1,300	96.1	200,000	118.0	24,000,000	138.8
1,400	96.5	225,000	118.5	26,000,000	139.0
1,500	96.8	250,000	119.0	28,000,000	139.5
1,600	97.0	275,000	119.4	30,000,000	139.8
1,700	97.3	300,000	119.8	32,500,000	140.1
1,800	97.6	350,000	120.4		
1,900	97.8	400,000	121.0		

*$TWA = 10 \times Log(D/100) + 85$

1.1.4 Ceiling Limit

Exposure to continuous, varying, intermittent, or impulsive noise shall not exceed 140 dBA.

1.2 Hearing Loss Prevention Program

The employer shall institute an effective hearing loss prevention program (HLPP) described in Sections 1.3 through 1.11 when any worker's 8-hr TWA exposure equals or exceeds 85 dBA.

1.3 Noise Exposure Assessment

The employer shall conduct a noise exposure assessment when any worker's 8-hr TWA exposure equals or exceeds 85 dBA. Exposure measurements shall conform to the *American National Standard Measurement of Occupational Noise Exposure*, ANSI S12.19–1996 [ANSI 1996a]. Noise exposure is to be measured without regard for the wearing of hearing protectors.

1.3.1 Initial Monitoring

When a new HLPP is initiated, an initial monitoring of the worksite or of noisy work tasks shall be conducted to determine the noise exposure levels representative of all workers whose 8-hr TWA noise exposures may equal or exceed 85 dBA. For workers remaining in essentially stationary, continuous noise levels, either a sound level meter or a dosimeter may be used. However, for workers who move around frequently or who perform different tasks with intermittent or varying noise levels, a task-based exposure monitoring strategy may provide a more accurate assessment of the extent of exposures.

1.3.2 Periodic Monitoring

If any worker's 8-hr TWA exposure to noise equals or exceeds 85 dBA, monitoring shall be repeated at least every 2 years. Monitoring shall be repeated within 3 months of the occurrence when there is a change in equipment, production processes or maintenance routines. It may also be prudent to assess noise exposures when work practices have changed and/or if workers are developing significant threshold shifts (see Section 1.6.4).

1.3.3 Instrumentation

Instruments used to measure workers' noise exposures shall be calibrated to ensure measurement accuracy and, at a minimum, they shall conform to the *American National Standard Specification for Sound Level Meters*, ANSI S1.4–1983 and S1.4A–1985, Type 2 [ANSI 1983, 1985] or, with the exception of the operating range, to the *American National Standard Specification for Personal Noise Dosimeters*, ANSI S1.25–1991 [ANSI 1991a]. If a sound level meter is used, the meter response shall be set at SLOW.

In determining TWA exposures, all continuous, varying, intermittent, and impulsive sound levels from 80 to 140 dBA shall be integrated into the noise measurements.

1.4 Engineering and Administrative Controls and Work Practices

To the extent feasible, engineering controls, administrative controls, and work practices shall be used to ensure that workers are not exposed to noise at or above 85 dBA as an 8-hr TWA. The use of administrative controls shall not result in exposing more workers to noise.

1.5 Hearing Protectors

Workers shall be required to wear hearing protectors when engaged in work that exposes them to noise that equals or exceeds 85 dBA as an 8-hr TWA.* The employer shall provide hearing protectors at no cost to the workers.

Hearing protectors shall attenuate noise sufficiently to keep the worker's "real-world" exposure (i.e., the noise exposure at the worker's ear when hearing protectors are worn) below 85 dBA as an 8-hr TWA. Workers whose 8-hr TWA exposures exceed 100 dBA should wear double hearing protection (i.e., they should wear earplugs and earmuffs simultaneously).†

To compensate for known differences between laboratory-derived attenuation values and the protection obtained by a worker in the real world, the labeled noise reduction ratings (NRRs) shall be derated as follows: (1) earmuffs—subtract 25% from the manufacturers' labeled NRR; (2) slow-recovery formable earplugs—subtract 50%; and (3) all other earplugs—subtract 70% from the manufacturers' labeled NRR. These derating values shall be used until such time as manufacturers test and label their products in accordance with a subject-fit method such as method B of ANSI S12.6–1997, *American National Standard Methods for Measuring the Real-Ear Attenuation of Hearing Protectors* [ANSI 1997]. Chapter 6 (p. 62) describes methods for using the NRR.

The employer shall train workers at least annually to select, fit, and use a variety of appropriate hearing protectors. By making a variety of devices available and training the workers in their use, the employer will substantially increase the likelihood that hearing protector use will be effective and worthwhile.

1.6 Medical Surveillance

The employer shall provide audiometry for all workers whose exposures equal or exceed 85 dBA as an 8-hr TWA.

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*This recommendation should not be construed to imply that workers need not wear hearing protection unless their 8-hr TWAs equal or exceed 85 dBA. For example, it would be prudent for a worker in and out of noise or habitually exposed to loud noise (e.g., 91 dBA for 1 hr and 59 min) to wear hearing protection while in noise—even though his or her dose was less than 100%.

†The intent of this section is not to advocate hearing protectors as the primary means of control; however, when engineering controls, administrative controls, and work practices cannot keep workers' exposures below 85 dBA as an 8-hr TWA, the use of hearing protectors shall be required. For most TWA exposures exceeding 105 dBA, hearing protectors will be necessary to supplement engineering and administrative controls.

1.6.1 Audiometry

Audiometric tests shall be performed by a physician, an audiologist, or an occupational hearing conservationist certified by the Council for Accreditation in Occupational Hearing Conservation (CAOHC) or the equivalent, working under the supervision of an audiologist or physician. The appropriate professional notation (e.g., licensure, certification, or CAOHC certification number) shall be recorded on each worker's audiogram.

Audiometric testing shall consist of air-conduction, pure-tone, hearing threshold measures at no less than 500, 1000, 2000, 3000, 4000, and 6000 hertz (Hz). Right and left ears shall be individually tested. The 8000-Hz threshold should also be tested as an option and as a useful source of information about the etiology of a hearing loss.

Audiometric tests shall be conducted with audiometers that meet the specifications of and are maintained and used in accordance with the *American National Standard Specifications for Audiometers*, ANSI S3.6–1996 [ANSI 1996b]. Audiometers shall receive a daily functional check, an acoustic calibration check whenever the functional check indicates a threshold difference exceeding 10 dB in either earphone at any frequency, and an exhaustive calibration check annually or whenever an acoustic calibration indicates the need—as outlined in Section 5.5.2. The date of the last annual calibration shall be recorded on each worker's audiogram.

Audiometric tests shall be conducted in a room where ambient noise levels conform to all requirements of the *American National Standard Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms*, ANSI S3.1–1991 [ANSI 1991b]. Instruments used to measure ambient noise shall conform to the *American National Standard Specification for Sound Level Meters,* ANSI S1.4–1983 and S1.4A–1985, Type 1 [ANSI 1983, 1985] and the *American National Standard Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters*, ANSI S1.11–1986 [ANSI 1986]. For permanent onsite testing facilities, ambient noise levels shall be checked at least annually. For mobile testing facilities, ambient noise levels shall be tested daily or each time the facility is moved, whichever is more often. Ambient noise measurements shall be obtained under conditions representing the typical acoustical environment likely to be present when audiometric testing is performed. Ambient noise levels shall be recorded on each audiogram or made otherwise accessible to the professional reviewer of the audiograms.

1.6.2 Baseline Audiogram

A baseline audiogram shall be obtained before employment or within 30 days of employment for all workers who must be enrolled in the HLPP. Workers shall not be exposed to noise levels at or above 85 dBA for a minimum of 12 hr before receiving a baseline audiometric test. Hearing protectors shall not be used in lieu of the required quiet period.

1.6.3 Monitoring Audiogram and Retest Audiogram

All workers enrolled in the HLPP shall have their hearing threshold levels (HTLs) measured annually. These audiometric tests shall be conducted during the worker's normal work shift. This audiogram shall be referred to as the "monitoring audiogram." The monitoring audiogram shall be examined immediately to determine whether a worker has a change in hearing relative to his or her baseline audiogram.

When the monitoring audiogram detects a change in the HTL in either ear that equals or exceeds 15 dB at 500, 1000, 2000, 3000, 4000, or 6000 Hz, an optional retest may be conducted immediately to determine whether the significant threshold shift is persistent. In most cases, the retest will demonstrate that the worker does *not* have a persistent threshold shift, thereby eliminating the need for a confirmation audiogram and followup action. If a persistent threshold shift *has* occurred, the worker shall be informed that his or her hearing may have worsened and additional hearing tests will be necessary.

1.6.4 Confirmation Audiogram, Significant Threshold Shift, and Followup Action

When a worker's monitoring audiogram detects a threshold shift as outlined in Section 1.6.3, he or she shall receive a confirmation audiogram within 30 days. This confirmation test shall be conducted under the same conditions as those of a baseline audiometric test. If the confirmation audiogram shows the persistence of a threshold shift, the audiograms and other appropriate records shall be reviewed by an audiologist or physician.

If this review validates the threshold shift, the threshold shift is considered to be a significant threshold shift. This shift shall be recorded in the worker's medical record, and the confirmation audiogram shall serve as the new baseline and shall be used to calculate any subsequent significant threshold shift. Whenever possible, the worker should receive immediate feedback on the results of his or her hearing test; however, in no case shall the worker be required to wait more than 30 days.

When a significant threshold shift has been validated, the employer shall take appropriate action to protect the worker from additional hearing loss due to occupational noise exposure. Examples of appropriate action include explanation of the effects of hearing loss, reinstruction and refitting of hearing protectors, additional training of the worker in hearing loss prevention, and reassignment of the worker to a quieter work area.

When the reviewing audiologist or physician suspects a hearing change is due to a nonoccupational etiology, the worker shall receive appropriate counseling, which may include referral to his or her physician.

1.6.5 Exit Audiogram

The employer should obtain an exit audiogram from a worker who is leaving employment or whose job no longer involves exposure to hazardous noise. The exit audiogram should be conducted under the same conditions as those of baseline audiometry.

1.7 Hazard Communication

1.7.1 Warning Signs

A warning sign shall be clearly visible at the entrance to or the periphery of areas where noise exposures routinely equal or exceed 85 dBA as an 8-hr TWA. All warning signs shall be in English and, where applicable, in the predominant language of workers who do not read English. Workers unable to read the warning signs shall be informed verbally about the instructions printed on signs in hazardous work areas of the facility. The warning sign shall textually or graphically contain the following information:

WARNING

NOISE AREA
HEARING HAZARD

Use of Hearing Protectors Required

1.7.2 Notification to Workers

All workers who are exposed to noise at or above 85 dBA as an 8-hr TWA shall be informed about the potential consequences of noise exposure and the methods of preventing noise-induced hearing loss (NIHL). When noise measurements are initially conducted and confirm the presence of hazardous noise, or when followup noise measurements identify additional noise hazards, workers shall be notified within 30 days. New workers shall be alerted about the presence of hazardous noise before they are exposed to it.

1.8 Training

The employer shall institute a training program in occupational hearing loss prevention for all workers who are exposed to noise at or above 85 dBA as an 8-hr TWA; the employer shall ensure worker participation in such a program. The training program shall be repeated annually for each worker included in the HLPP. Information provided shall be updated to be consistent with changes in protective equipment and work processes.

The employer shall ensure that the training addresses, at a minimum, (1) the physical and psychological effects of noise and hearing loss; (2) hearing protector selection,

fitting, use, and care; (3) audiometric testing; and (4) the roles and responsibilities of both employers and workers in preventing NIHL.

The format for the training program may vary from formal meetings to informal on-the-spot presentations. Allowances shall be made for one-on-one training, which would be particularly suitable for workers who have demonstrated a significant threshold shift. Whenever possible, the training should be timed to coincide with feedback on workers' hearing tests.

The employer shall maintain a record of educational and training programs for each worker for the duration of employment plus 1 year. On termination of employment, the employer should provide a copy of the training record to the worker. The employer may wish to keep the training record with the worker's exposure and medical records for longer durations (see Section 1.10).

1.9 Program Evaluation Criteria

The effectiveness of the HLPP shall be evaluated at the level of the individual worker and at the programmatic level.

The evaluation at the worker level shall take place at the time of the annual audiometry. If a worker demonstrates a significant threshold shift that is presumed to be occupationally related, all possible steps shall be taken to ensure that the worker does not incur additional occupational hearing loss.

The evaluation at the programmatic level shall take place annually. The incidence rate of significant threshold shift for noise-exposed workers shall be compared with that for a population not exposed to occupational noise. Similar incidence rates from this comparison indicate an effective HLPP. Data for calculating an incidence rate for a population not exposed to occupational noise should be drawn from Annex C in the *American National Standard Determination of Occupational Noise Exposure and Estimation of Noise-Induced Hearing Impairment*, ANSI S3.44–1996 [ANSI 1996c] unless more appropriate data are available.

1.10 Recordkeeping

The employer shall establish and maintain records in accordance with the requirements in Sections 1.10.1 through 1.10.5.

1.10.1 Exposure Assessment Records

The employer shall establish and maintain an accurate record of all exposure measurements required in Section 1.3. These records shall include, at a minimum, the name of the worker being monitored; identification number; duties performed and job locations; dates and times of measurements; type (refer to Section 6), brand, model, and size of hearing protectors used (if any); the measured exposure levels; and the identification of the person taking the measurements. Copies of a worker's exposure history resulting

from this requirement shall also be included in the worker's medical file along with the worker's audiograms.

1.10.2 Medical Surveillance Records

The employer shall establish and maintain an accurate record for each worker subject to the medical surveillance specified in Section 1.6. These records shall include, at a minimum, the name of the worker being tested; identification number; duties performed and job locations; medical, employment, and noise-exposure history; dates, times, and types of tests (i.e., baseline, annual, retest, confirmation); hours since last noise exposure before each test; HTLs at the required audiometric frequencies; tester's identification and assessment of test reliability; the etiology of any significant threshold shift; and the identification of the reviewer.

1.10.3 Record Retention

In accordance with the requirements of 29 CFR[‡] 1910.20(d), Preservation of Records, the employer shall retain the records described in Sections 1.3 and 1.6 of this document for at least the following periods:

- 30 years for noise exposure monitoring records
- Duration of employment plus 30 years for medical monitoring records

In addition, records of audiometer calibrations and the ambient noise measurements in the audiometric testing room shall be maintained for 5 years.

1.10.4 Availability of Records

In accordance with 29 CFR 1910.20, Access to Employee Exposure and Medical Records, the employer shall, upon request, allow examination and provide copies of these records to a worker, a former worker, or anyone having appropriate authorization for record access.

1.10.5 Transfer of Records

The employer shall comply with the requirements for the transfer of records as set forth in 29 CFR 1910.20(h), Transfer of Records.

1.11 ANSI Standards

All standards (e.g., American National Standards Institute [ANSI] standards) referred to in this document shall be superseded by the latest available versions.

[‡]*Code of Federal Regulations*. See CFR in references.