# I. RECOMMENDATIONS FOR A NOISE STANDARD

The National Institute for Occupational Safety and Health (NIOSH) recommends that employee exposure to noise in the workplace be controlled by requiring compliance with the standard set forth in the following sections. Control of employee exposure to the occupational limits stated and adherence to the precautionary procedures prescribed will improve the protection of the working population from incurring noise induced hearing loss that could impair their abilities to understand everyday speech. Such control and adherence at the workplace is believed sufficiently effective to reduce also the possibility of other forms of occupational injury and illness related to noise.

This standard is amenable to techniques that are valid, reproducible, and presently available. It will be reviewed and revised as additional information becomes available.

Section 1 - <u>Applicability</u>

The provisions of this standard are applicable to occupational noise exposures at places of employment and are intended to apply for all noise even though additional controls may be necessary for certain specific types of noise, such as some impact and impulsive noise. For the purposes of this standard the noise exposure is determined for an 8-hour workday.

Section 2 - <u>Definitions</u>

As used in this standard, the term:

(a) "Administrative control" means any procedure that limits daily exposure to noise by control of the work schedule.

(b) "Audiogram" means a graph or table obtained from an audiometric examination showing hearing level as a function of frequency.

(c) "Baseline audiogram" means an audiogram obtained from an audiometric examination that is preceded by a period of at least 14 hours of quiet.

(e) "Audiometer setting" means a setting on an audiometer corresponding to a specific combination of hearing level and sound frequency.


(f) "Daily Noise Dose" means that value for D derived from the equation:

$$D = \frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots + \frac{C_n}{T_n}$$

where C1, C2 . . . , Cn are the actual durations of exposure for an employee at the various noise levels, T1, T2, . . . , Tn are the respective duration limits obtained from Figure I-1 and D is the Daily Noise Dose.

(g) "dBA - Slow" means the unit of measurement of sound level indicated by a sound level meter conforming as a minimum requirement to the American National Standard Specification for Sound Level Meters, ANSI S1.4 (1971) Type S2A, when used for A-weighted sound level, slow response.

(h) "Engineering control" means any procedure other than administrative control that reduces the sound level either at the source of the noise or in the hearing zone of the employees.

(i) "Hearing level" means the amount, in decibels, by which the threshold of audibility for an ear differs from a standard audiometric threshold.

(j) "Environmental noise level" means the noise level in dBA-Slow as measured in accord with Section 3(c).

(k) "Effective noise level" means (1) for employees not wearing ear protectors, the environmental noise level; (2) for employees wearing ear protectors, the result of subtracting the dBA reduction, R, for the ear protectors (determined as specified in Appendix A) from the measured environmental noise level. Effective noise level is expressed in units of dBA-Slow.

(1) "Noise exposure" means a combination of effective noise level and exposure duration.

Section 3 - Occupational Environment

(a) The unit of measurement shall be "dBA-Slow."

(b) Daily Occupational Noise Exposure

(i) Occupational noise exposure shall be controlled so that no worker shall be exposed in excess of the limit described as line B in Figure I-1. New installations shall be designed with noise control so that the noise exposure does not exceed the limits described as line A in Figure I-1. For noise exposures consisting of two or more periods of exposure at different levels, the Daily Noise Dose, D, shall not exceed unity. Line A or line B, as applicable, shall be used in computing the Daily Noise Dose.

(ii) It is recommended that the limit described as line A become effective for all places of employment after a time period determined by the Secretary of Labor in consultation with the Secretary of Health, Education, and Welfare. This delay in effective date for all places of

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LINE A
FORMULA:   T = 16 ÷ 2$^{(L-80)/5}$
RANGE:   80 to 115 dBA-Slow

LINE B
FORMULA:   T = 16 ÷ 2$^{(L-85)/5}$
RANGE:   85 to 115 dBA-Slow
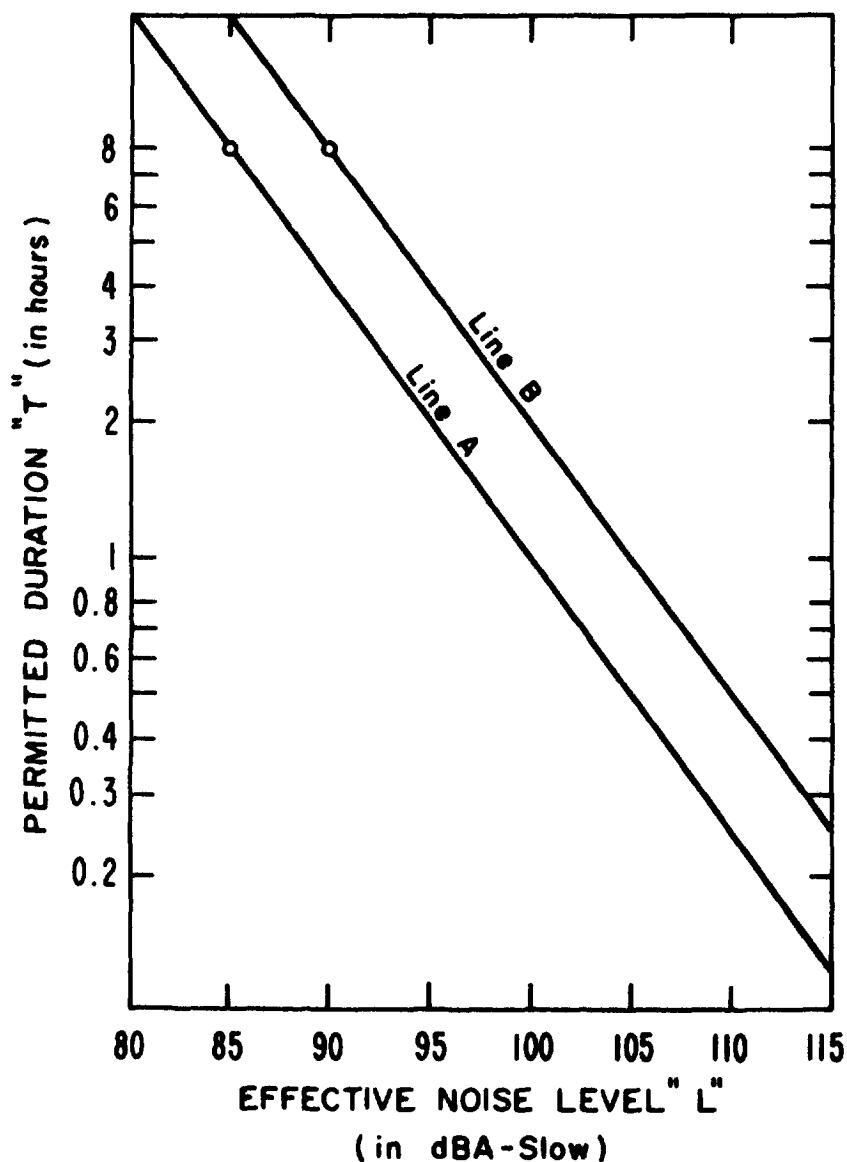
Figure I-1. Permitted duration vs. noise level.*

*The indicated duration limits which exceed 8 hours are
to be used only for purposes of computing Daily Noise
Dose and are not to be regarded as defining noise
exposure limits for work days which exceed 8 hours.

employment is believed necessary to permit the Department of Labor to conduct an extensive feasibility study.

(iii) At no time shall any worker be exposed to effective noise levels exceeding 115 dBA-Slow.

(c) Measurements

(i) Compliance with the permitted daily noise exposures defined by Section 3(b) shall be determined on the basis of measurements made with a sound level meter conforming as a minimum to the requirement of the American National Standard Specification for Sound Level Meters, S1.4 (1971) Type S2A, and set to use an A-weighted slow response.

(ii) All measurements shall be made with the sound level meter at a position which most closely approximates the noise levels at the head position of the employee during normal operations.

(iii) An acoustical calibrator accurate within plus or minus one decibel shall be used to calibrate the sound level meter on each day that noise measurements are taken.

Section 4 - Medical

(a) Medical surveillance in the form of an audiometric testing program shall be provided by the employer when the Daily Noise Dose, D, equals or exceeds the limits specified in Section 3(b), and for all employees whose occupational noise exposure is controlled by personal protective equipment.

(b) The audiometric testing program required by (a) above shall conform to the following schedule:

(i) A baseline audiogram for each employee who is initially assigned or reassigned to work subject to conditions stated in (a) of this section shall be taken within 30 days of assignment to such employment, in the sixth year of such employment, and once every sixth year thereafter. It is recognized that some delay in implementation of this requirement may be necessary for employers with a small work force.

(ii)  A baseline audiogram should be taken for each employee presently assigned to work subject to conditions stated in (a) of this section at the time of effective date of this regulation, in the sixth year, and once every sixth year thereafter.

(iii)  In addition an audiogram, not necessarily baseline, for all exposed employees should be taken every second year.

(c)  Each audiogram shall contain (1) employee's name or identifying number, (2) employee's job location, (3) significant aural medical history of the employee, (4) the examiner's name and signature, (5) the date and time of test, (6) serial number of the audiometer, and (7) last exposure to high level noise: number of hours since exposure; type of exposure; and noise level, if known.

(d)  Each employee's audiogram shall be examined to determine whether it indicates for either ear any threshold shift (higher threshold), that equals or exceeds 10 dB at 500, 1000, 2000, or 3000 Hz, or 15 dB at 4000 or 6000 Hz as evidenced by a comparison of that audiogram with the employee's most recent baseline audiogram and with his initial baseline audiogram as corrected to his current age by the method described in Appendix B.  If either comparison indicates a shift as described above:

(i)  refer the employee for appropriate medical evaluation,

(ii)  if the employee needs personal protective equipment or devices, insure that he has the appropriate effective equipment and that he is instructed in the proper use and care of the equipment, and

(iii)  if the audiogram was not a baseline audiogram, take a baseline audiogram within sixty days.

(e)  Audiometric tests shall be pure tone, air-conduction, hearing threshold examinations, with test frequencies including 500, 1000, 2000, 3000, 4000, and 6000 Hz and shall be taken separately for the right and left ears.

(i) The tests shall be conducted in a room whose ambient noise levels conform to all requirements except that part concerning octave bands whose center frequencies are less than 250 Hz of the American National Standard Criteria for Background Noise in Audiometer Rooms, ANSI S3.1 (1960 R-1971), when measured by equipment conforming to American National Standard Specification for Sound Level Meters, ANSI S1.4 (1971) Type 2 and American National Standard Specification for Octave, Half-Octave, and Third-Octave Band Filter Sets, ANSI S1.11 (1966, R-1971).

(ii) The tests shall be administered using an audiometer which conforms to the requirements for limited range pure tone audiometers prescribed by the American National Standards Specifications for Audiometers, ANSI S3.6 (1969), and which is of the discrete frequency type. If a pulsed tone audiometer is used, the on-time of the tone shall be at least 200 milliseconds. The instrument used in the testing shall be either a manual audiometer, or a self-recording audiometer which is subject to the following additional restrictions:

(1) The chart upon which the audiogram is traced shall have printed lines at positions corresponding to all multiples of 10 dB hearing level within the intensity range spanned by the audiometer. The lines shall be equally spaced and shall be separated by at least 1/4 inch. Additional graduations are optional. The pen which traces the audiogram shall have a fine point so that the tracing shall not exceed 2 dB in width.

(2) It shall be possible to disable the stylus drive

mechanism so that the stylus can be manually set at the 10-dB graduation lines for calibration purposes.

(3) The slewing rate for the audiometer attenuator shall be 6 dB/sec or less except that an initial slewing rate greater than 6 dB/sec is permitted at the beginning of each new test frequency, but only until the second subject response.

(4) The audiometer shall remain at each required test frequency for 30 seconds (± 3 seconds). The audiogram shall be clearly marked at each change of frequency and the actual frequency change of the audiometer shall not deviate from the frequency boundaries marked on the audiogram by more than ± 3 seconds.

(5) If an audiogram fails to pass the following criteria, the subject shall be retested:

At each test frequency it must be possible to place a horizontal line segment parallel to the time axis on the audiogram, such that the audiometric tracing crosses the line segment at least six times at that test frequency.

(iv) The audiometer shall be maintained in calibration in accordance with the provisions of Appendix C.

Section 5 - Work Practices

When employees are employed under conditions where noise exposures would exceed the limits prescribed in Section 3(b), administrative or engineering controls shall be utilized to reduce exposures to within those limits.

Section 6 - Warning Notice

(a)  A warning sign shall be appropriately located at entrances to and/or the periphery of, areas where there exists sustained environmental noise at or in excess of the limit prescribed in Section 3(b).

(b)  The notice shall consist of the following:

<center>

W A R N I N G

NOISE AREA
MAY CAUSE HEARING LOSS

Use Proper Ear Protection
</center>

Section 7 - <u>Personal Protective Equipment</u>

(a)  If noise exposures to which employees could be exposed exceed the limits specified, personal protective equipment (i.e., ear protectors) shall be provided by the employer to be used in conjunction with an audiometric testing program, as specified in Section 4, subject to the following requirements:

(i)  The use of personal protective equipment to prevent occupational noise exposure of the employer in excess of the prescribed limits is authorized only until engineering and administrative controls and procedures can be implemented to maintain the occupational noise exposures within prescribed limits.

(ii)  Any ear protector used by an employee shall reduce the effective noise level to which he is exposed so that his noise exposure is within the limits prescribed in Section 3(b).

(iii)  Insert - type ear protectors shall be fitted by a person trained in this procedure.

(iv)  Inspection procedures to assure proper issuance, maintenance, and use of personal protective equipment shall be established by the employer.

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(b)  The employer shall provide training in the proper care and use
of all personal protective equipment.

Section 8 - <u>Apprisal of Employees of Hazards from Noise</u>

Each worker exposed to noise shall be apprised of all hazards, relevant
symptoms, and proper conditions and precautions for working in noisy areas.
The information shall be kept on file and readily accessible to the worker
at all places of employment where the noise levels equal or exceed the limits
prescribed in Section 3 (b).

Section 9 - <u>Monitoring & Recordkeeping Requirements</u>

(a)  Employers will be required to maintain records of:

(i)  environmental exposure monitoring for a period of 10 years.

(ii)  all audiograms for a period of 20 years.

(iii)  all audiometric calibration data for a period of 20 years.

(b)  When exposure times of less than 8 hours/day are required in
a specific work area or ear protection is used to meet the exposure
limits, records of the method of control shall be maintained.

# Appendix A - <u>Determination of dBA Reduction R for Ear Protectors</u>

1. The pure tone attenuation vs. frequency characteristics of the ear

protector (normally supplied by the manufacturer) shall have been determined

in accordance with the American National Standard for Measurement of the

Real-Ear Attenuation of Ear Protectors at Threshold, ANSI Z24.22 (1957).

Let $Q_1$, $Q_2$, . . ., $Q_7$ be defined (in dB) as follows:

$Q_1$ = attenuation at 125 Hz, plus 16.2 dB

$Q_2$ = attenuation at 250 Hz, plus 8.7 dB

$Q_3$ = attenuation at 500 Hz, plus 3.3 dB

$Q_4$ = attenuation at 1000 Hz

$Q_5$ = attenuation at 2000 Hz, minus 1.2 dB

$Q6$ = average of attenuation at 3000 and 4000 Hz, minus 1.0 dB

$Q_7$ = average of attenuations at 6000 and 8000 Hz, plus 1.1 dB

2. The following procedure shall be used to determine the dBA reduction R

of the ear protector when used for an occupational noise whose octave-band

sound pressure levels have been measured.

Let $L_1$, $L_2$, $L_3$, $L_4$, $L_5$, $L_6$ and $L_7$ denote the octave band levels in

dB at 125, 250, 500, 1000, 2000, 4000, and 8000 Hz respectively; and let

$L_A$ denote the dBA-Slow level of the noise. Then the dBA reduction as

connected is given by $R = L_A - 10 \log S - 10.0$

where

$S$ = antilog $(0.1X [L_1 - Q_1])$ + antilog $(0.1 X [L_2 - Q_2])$

+ antilog $(0.1 X [L_3 - Q_3])$ + antilog $(0.1 X [L_4 - Q_4])$

+ antilog $(0.1 X [L_5 - Q_5])$ + antilog $(0.1 X [L_6 - Q_6])$

+ antilog $(0.1 X [L_7 - Q_7])$

The "-10.0" correction term is to account for possible noise spectrum irregularities and noise leakage which might be caused by long hair, safety glasses, head movement, or various other factors.

3.  If the octave band levels of the noise are not known, then the dBA reduction R may be computed simply as

   $R = -10 \log S - 3.0$

   where

   $S = \text{antilog } (-0.1 \times Q_1) + \text{antilog } (-0.1 \times Q_2)$

   $+ \text{antilog } (-0.1 \times Q_3) + \text{antilog } (-0.1 \times Q_4)$

   $+ \text{antilog } (-0.1 \times Q_5) + \text{antilog } (-0.1 \times Q_6)$

   $+ \text{antilog } (-0.1 \times Q_7)$

This calculation is approximate, and is based upon the assumption that the octave band levels are equal. For most types of noise it will give results close to those obtained by the more accurate method of (2) above. Example:

Typical Pure-tone Attenuation Characteristics of an Ear Protector

| 125 | 250 | 500 | 1000 | 2000 | 3000 | 4000 | 6000 | 8000 | Hz |
|-----|-----|-----|------|------|------|------|------|------|-----|
| 24  | 21  | 23  | 29   | 30   | 35   | 31   | 29   | 27   | dB  |

Thus $Q_1 = 40.2$; $Q_2 = 29.7$; $Q_3 = 26.3$; $Q_4 = 29.0$; $Q_5 = 28.8$; $Q_6 = 31.0$;

   $Q_7 = 29.1$

If the octave band noise levels are not known, then

   $R = -10 \log S - 3.0$

   where

$S = \text{antilog } (-4.02) + \text{antilog } (-2.97) + \text{antilog } (-2.63)$

   $+ \text{antilog } (-2.90) + \text{antilog } (-2.88) + \text{antilog } (-3.10)$

   $+ \text{antilog } (-2.91)$

or S = 0.00811

So R = -10 log. 0.0081 - 3.0 = 20.9 - 3.0 ≈ 18 dBA

Now suppose the ear protector is to be used in an area with an environmental noise level of 95 dBA, for which the octave band noise levels are as follows:

| 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 | Hz |
|-----|-----|-----|------|------|------|------|-----|
| 99 | 94 | 94 | 90 | 84 | 82 | 75 | Octave Band Level |

In this case the dBA reduction is

$R = L_A = 10 \log S - 10.0$

Where S = antilog (9.9 - 4.02) + antilog (9.4 - 2.97) + antilog (9.4 - 2.63)

+ antilog (9.0 - 2.90) + antilog (8.4 - 2.88) + antilog (8.2 - 3.10)

+ antilog (7.5 - 2.91). So S = 11,090,000

Thus R = 95.0 - 10 x 7.05 - 10.0 ≈ 85.0 - 70.5

So R = 14.5 dBA

Appendix B - <u>Method for Correcting Initial Baseline Audiograms for Age</u>

Age corrections to initial baseline audiograms shall be made in the following manner:

For each audiometric test frequency:

1. Determine from Table B-1 or B-2 the age correction values for the employee

      (a) for the age at which the most recent audiogram was taken and

      (b) for the age at which the initial baseline audiogram was taken.

2. Subtract the values found in (a) from the values found in (b).

3. Add the difference found in 2 to the employee's initial baseline audiogram to obtain the initial baseline audiogram corrected for age.

EXAMPLE: Employee is 56 years old and male. His initial baseline audiogram was taken at age 26 and his hearing levels at that age were as follows:

| Hz | 500 | 1000 | 2000 | 3000 | 4000 | 6000 |
|----|-----|------|------|------|------|------|
| Left ear | 5 | 0 | 10 | 5 | 10 | 10 |
| Right ear | 10 | 0 | 5 | 0 | 5 | 15 |

Enter Table B-1 at age 56 and at age 26 and subtract.

| Hz | 500 | 1000 | 2000 | 3000 | 4000 | 6000 |
|----|-----|------|------|------|------|------|
| Age 56 | 16 | 10 | 11 | 20 | 28 | 34 |
| Age 26 | 11 | 5 | 4 | 5 | 7 | 10 |
| Difference | 5 | 5 | 7 | 15 | 21 | 24 |

Add the differences to his initial baseline audiogram to obtain his corrected initial baseline audiogram as follows:

| Hz | 500 | 1000 | 2000 | 3000 | 4000 | 6000 |
|---|---|---|---|---|---|---|
| Left ear | 10 | 5 | 18 | 20 | 31 | 34 |
| Right ear | 15 | 5 | 13 | 15 | 26 | 39 |

Age Corrections Values to be Used for Age Correction
of Initial Baseline Audiograms for Males

| Age<br>Years | Audiometric Test Frequencies (Hz) | | | | | |
|---|---|---|---|---|---|---|
| | 500 | 1000 | 2000 | 3000 | 4000 | 6000 |
| 20 or younger | 10 | 5 | 3 | 4 | 5 | 8 |
| 21 | 10 | 5 | 3 | 4 | 5 | 8 |
| 22 | 10 | 5 | 3 | 4 | 5 | 8 |
| 23 | 10 | 5 | 3 | 4 | 6 | 9 |
| 24 | 10 | 5 | 3 | 5 | 6 | 9 |
| 25 | 11 | 5 | 3 | 5 | 7 | 10 |
| 26 | 11 | 5 | 4 | 5 | 7 | 10 |
| 27 | 11 | 5 | 4 | 6 | 7 | 11 |
| 28 | 11 | 6 | 4 | 6 | 8 | 11 |
| 29 | 11 | 6 | 4 | 6 | 8 | 12 |
| 30 | 11 | 6 | 4 | 6 | 9 | 12 |
| 31 | 12 | 6 | 4 | 7 | 9 | 13 |
| 32 | 12 | 6 | 5 | 7 | 10 | 14 |
| 33 | 12 | 6 | 5 | 7 | 10 | 14 |
| 34 | 12 | 6 | 5 | 8 | 11 | 15 |
| 35 | 12 | 7 | 5 | 8 | 11 | 15 |
| 36 | 12 | 7 | 5 | 9 | 12 | 16 |
| 37 | 13 | 7 | 6 | 9 | 12 | 17 |
| 38 | 13 | 7 | 6 | 9 | 13 | 17 |
| 39 | 13 | 7 | 6 | 10 | 14 | 18 |
| 40 | 13 | 7 | 6 | 10 | 14 | 19 |
| 41 | 13 | 7 | 6 | 11 | 15 | 20 |
| 42 | 14 | 8 | 7 | 11 | 16 | 20 |
| 43 | 14 | 8 | 7 | 12 | 16 | 21 |
| 44 | 14 | 8 | 7 | 12 | 17 | 22 |
| 45 | 14 | 8 | 7 | 13 | 18 | 23 |
| 46 | 14 | 8 | 8 | 13 | 19 | 24 |
| 47 | 14 | 8 | 8 | 14 | 19 | 24 |
| 48 | 15 | 9 | 8 | 14 | 20 | 25 |
| 49 | 15 | 9 | 9 | 15 | 21 | 26 |
| 50 | 15 | 9 | 9 | 16 | 22 | 27 |
| 51 | 15 | 9 | 9 | 16 | 23 | 28 |
| 52 | 15 | 9 | 10 | 17 | 24 | 29 |
| 53 | 16 | 9 | 10 | 18 | 25 | 30 |
| 54 | 16 | 10 | 10 | 18 | 26 | 31 |
| 55 | 16 | 10 | 11 | 19 | 27 | 32 |
| 56 | 16 | 10 | 11 | 20 | 28 | 34 |
| 57 | 16 | 10 | 11 | 21 | 29 | 35 |
| 58 | 17 | 10 | 12 | 22 | 31 | 36 |
| 59 | 17 | 11 | 12 | 22 | 32 | 37 |
| 60 or older | 17 | 11 | 13 | 23 | 33 | 38 |

## Age Corrections Values to be Used for Age Correction
## of Initial Baseline Audiograms for Females

| Age Years | Audiometric Test Frequencies (Hz) | | | | | |
|---|---|---|---|---|---|---|
| | 500 | 1000 | 2000 | 3000 | 4000 | 6000 |
| 20 or younger | 15 | 7 | 4 | 3 | 3 | 6 |
| 21 | 16 | 7 | 4 | 4 | 3 | 6 |
| 22 | 16 | 7 | 4 | 4 | 4 | 6 |
| 23 | 16 | 7 | 5 | 4 | 4 | 7 |
| 24 | 16 | 7 | 5 | 4 | 4 | 7 |
| 25 | 16 | 8 | 5 | 4 | 4 | 7 |
| 26 | 16 | 8 | 5 | 5 | 4 | 8 |
| 27 | 17 | 8 | 5 | 5 | 5 | 8 |
| 28 | 17 | 8 | 5 | 5 | 5 | 8 |
| 29 | 17 | 8 | 5 | 5 | 5 | 9 |
| 30 | 17 | 8 | 6 | 5 | 5 | 9 |
| 31 | 17 | 8 | 6 | 6 | 5 | 9 |
| 32 | 17 | 9 | 6 | 6 | 6 | 10 |
| 33 | 18 | 9 | 6 | 6 | 6 | 10 |
| 34 | 18 | 9 | 6 | 6 | 6 | 10 |
| 35 | 18 | 9 | 6 | 7 | 7 | 11 |
| 36 | 18 | 9 | 7 | 7 | 7 | 11 |
| 37 | 18 | 9 | 7 | 7 | 7 | 12 |
| 38 | 18 | 10 | 7 | 7 | 7 | 12 |
| 39 | 19 | 10 | 7 | 8 | 8 | 12 |
| 40 | 19 | 10 | 7 | 8 | 8 | 13 |
| 41 | 19 | 10 | 8 | 8 | 8 | 13 |
| 42 | 19 | 10 | 8 | 9 | 9 | 13 |
| 43 | 19 | 11 | 8 | 9 | 9 | 14 |
| 44 | 20 | 11 | 8 | 9 | 9 | 14 |
| 45 | 20 | 11 | 8 | 10 | 10 | 15 |
| 46 | 20 | 11 | 9 | 10 | 10 | 15 |
| 47 | 20 | 11 | 9 | 10 | 11 | 16 |
| 48 | 20 | 12 | 9 | 11 | 11 | 16 |
| 49 | 21 | 12 | 9 | 11 | 11 | 16 |
| 50 | 21 | 12 | 10 | 11 | 12 | 17 |
| 51 | 21 | 12 | 10 | 12 | 12 | 17 |
| 52 | 21 | 12 | 10 | 12 | 13 | 18 |
| 53 | 21 | 13 | 10 | 13 | 13 | 18 |
| 54 | 21 | 13 | 11 | 13 | 14 | 19 |
| 55 | 22 | 13 | 11 | 14 | 14 | 19 |
| 56 | 22 | 13 | 11 | 14 | 15 | 20 |
| 57 | 22 | 13 | 11 | 15 | 15 | 20 |
| 58 | 22 | 14 | 12 | 15 | 16 | 21 |
| 59 | 22 | 14 | 12 | 16 | 16 | 21 |
| 60 or older | 23 | 14 | 12 | 16 | 17 | 22 |

Appendix C - <u>Procedures for Calibration of Audiometers</u>

The accuracy of an audiometer shall be determined by (1) a biological calibration, (2) a periodic calibration, and (3) an exhaustive calibration.

A.  A biological calibration shall be made at least once each month and shall consist of (1) testing a person having a known stable audiometric curve that does not exceed 25 dB hearing level at any frequency and comparing the test results with the known curve and (2) registering the subject's response to distortions and unwanted sounds from the audiometer.  If the results of a biological calibration indicate hearing-level differences greater than $\pm 5$ dB at any frequency, if the signal is distorted, or if there are attenuator or tone switch transients, then the audiometer shall be subjected to a periodic calibration within thirty days.

B.  A periodic calibration shall be performed at least annually or as indicated by results of a biological check and shall include the following:

(1)  Set audiometer to 70 dB hearing threshold level and measure sound pressure levels of test tones using an NBS-9A-type coupler, for both earphones and at all test frequencies.

(2)  At 1000 Hz, for both earphones measure the earphone decibel levels of the audiometer for 10 dB settings in the range 70 to 10 dB hearing threshold level.  This measurement may be made acoustically with a 9A coupler, or electrically at the earphone terminals.

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(3)  Measure the test tone frequencies with the audiometer set at 70 dB hearing threshold level, for one earphone only.

(4)  In making the measurements in (1) - (3) above the accuracy of the calibrating equipment shall be sufficient to prove that the audiometer is within the tolerances permitted by ANSI S3.6-1969.

(5)  A careful listening test, more extensive than that required in the biological calibration, shall be made in order to ensure that the audiometer displays no evidence of distortion, unwanted sound, or other technical problems.

(6)  General function of the audiometer shall be checked, particularly in the case of a self-recording audiometer.

(7)  All observed deviations from required performance shall be corrected.

C.  An exhaustive calibration shall be performed at least every five years. This shall include testing at all settings for both earphones. The test results must prove unequivocally that the audiometer meets for the following parameters the specific requirements stated in the applicable sections of ANSI-S.3-1969 as noted in parenthesis.

(1)  Accuracy of decibel level settings of test tones (Sections 4.1.4.1 and 4.1.4.3).

(2)  Accuracy of test tone frequencies (Section 4.1.2).

(3)  Harmonic distortion of test tones (Section 4.1.3).

(4)  Tone-envelope characteristics, i.e., rise and decay times, overshoot, "off" level (Section 4.5).

(5)  Sound from second earphone (Section 4.4.2).

(6)  Sound from test earphone (Section 4.4.1).

(7)  Other unwanted sound (Section 4.4.3).

## II.  INTRODUCTION

The sounds of industry, growing in volume over the years, have
heralded not only technical and economic progress, but also the threat
of an ever increasing incidence of hearing loss and other noise related
disturbances to exposed employees.  Noise is not a new hazard.  Indeed,
noise-induced hearing loss was observed centuries ago.  Ramazzini in
"De Morbis Artificium Diatriba" in 1700 described how those hammering
copper "have their ears so injured by that perpetual din.....that
workers of this class became hard of hearing and, if they grow old at
this work, completely deaf."  Before the Industrial Revolution, however,
comparatively few people were exposed to high level workplace noise.
It was the advent of steam power in connection with the Industrial
Revolution that first brought general attention to noise as an occupational
hazard.  Workers who fabricated steam boilers were found to develop
hearing loss in such numbers that such a malady was dubbed "boilermakers
disease."  Increasing mechanization in all industries and most trades
has since proliferated the noise problem.

Federal efforts to effectively regulate occupational noise in the
United States were begun about 1955.  The military was first to establish
such regulations for members of the armed forces.  Under the Walsh-
Healey Public Contracts Act of 1936, as amended, safety and health
standards had been issued that contained references to excessive noise,
but they prescribed neither limits nor acknowledged the occupational
hearing loss problem.  A later regulation under this act (41 CFR 50-
204.10) promulgated in 1969, defined noise limits for occupational

exposure for purposes of hearing conservation. These limits were applicable to only those firms having supply contracts with the government in excess of $10,000; similar limits were made applicable to work under Federal Service contracts of $2,500 or more under the Service Contract Act. The noise rule in the Walsh-Healey Act regulations was adopted under the Coal Mine Health and Safety Act of 1969 and thereby became applicable to underground and surface coal mine operations as amended on July 7, 1971 (Federal Register, Vol. 36, No. 130, p. 12739).

In 1970, the Occupational Safety and Health Act was enacted which stipulated that the Secretary of Health, Education, and Welfare would on the basis of available data develop criteria for harmful physical agents that describe exposure levels safe for various periods of employment. In compliance with this provision, it is the intent of this document to present the criteria and a recommended standard based thereon for preventing occupational hazards arising from workplace noise. The recommended limits for safe exposure are primarily designed to conserve hearing since this is recognized as the most serious physical problem that noise may cause in humans. For other disturbances connected with noise such as stress related illness and performance losses, there is insufficient or inconclusive evidence upon which to base a standard. It should be emphasized, however, that adherence to noise limits for hearing conservation will also reduce risks of any other noise related problems.

Currently NIOSH reluctantly concurs with the generally acceptable 90 dBA occupational exposure level for an 8 hour day. The need for reducing this 8 hour exposure level to 85 dBA, as supported by the material contained in this document is also recognized. It is recommended that the 85 dBA, 8 hour exposure level be applicable to all newly designed occupational exposure environments after 6 mos. from the effective date of this standard. However, due to the unavailability of sufficient data relating to the technological feasibility of meeting the 85 dBA level, NIOSH is unable to recommend a specific time period after which the 85 dBA, 8 hour occupational exposure level might become effective for all occupational noise environments.

In accord with other provisions of the Occupational Safety and Health Act of 1970, this document also presents prescribed methods for measuring noise, calculating noise exposure, providing medical services and a hearing conservation program, environmental monitoring, and recordkeeping.

# III. ACOUSTICAL TERMS AND METHODS

## Definitions [4]

Ambient Noise - Ambient noise is the all-encompassing noise associated with a given environment, being usually a composite of sounds from many sources near and far.

Band Pressure Level - The band pressure level of a sound for a specified frequency band is the sound pressure level for the sound contained within the restricted band. The reference pressure must be stated. The band may be specified by its lower and upper cut-off frequencies, or by its geometric center frequency and bandwidth. The width of the band may be indicated by a prefatory modifier; e.g., octave band (sound pressure) level, half-octave band level, third-octave band level, 50-cps band level.

Cycle - A cycle is the complete sequence of values of a periodic quantity that occur during a period.

Damping - Damping is the dissipation of energy with time or distance.

Decibel - the decibel is a unit of level whenever the base of the logarithm is the tenth root of ten and the quantities concerned are proportional to power. The logarithm to the base the tenth root of 10 is the same as ten times the logarithm to the base 10; e.g., for a number $X^2$, $\log_{10}^{1/10} X^2 = 10 \log_{10} X^2 = 20 \log_{10} X$. This last relationship is the one ordinarily used to simplify the language in definitions of sound pressure level.

Effective Sound Pressure (Root-Mean-Square Sound Pressure) - The effective sound pressure at a point is the root-mean-square value of the instantaneous sound pressures over a time interval at the point under consideration. In the case of periodic sound pressures, the interval must be an integral number of periods or an interval that is long compared to a period.

Frequency - The frequency of a function periodic in time is the reciprocal of the primitive period. The unit is the cycle per unit time and must be specified. The unit cycle per second is commonly called Hertz (Hz).

Level - In acoustics, the level of a quantity is the logarithm of the ratio of that quantity to a reference quantity of the same kind. The base of the logarithm, the reference quantity, and the kind of level must be specified.

Noise - (1) Noise is any undesired sound; and, by extension, noise is any unwanted disturbance within a useful frequency band, such as undesired electric waves in a transmission channel or device. (2) Noise is an erratic, intermittent, or statistically random oscillation. Since the definitions of noise are not mutually exclusive, it is usually necessary to depend upon context for the distinction.

Noise Level - (1) Noise level is the level of noise, the type of which must be indicated by further modifier or context. The physical quantity measured (e.g., voltage), the reference quantity, the instrument used, and the bandwidth or other weighting characteristic must be indicated. (2) For airborne sound, unless specified to the contrary, noise level is the weighted sound pressure level called sound level; the weighting must be indicated.

Oscillation - Oscillation is the variation, usually with time, of the magnitude of a quantity with respect to a specified reference when the magnitude is alternately greater and smaller than the reference.

Period — The period of a periodic quantity is the smallest increment of the independent variable for which the function repeats itself.

Periodic Quantity - A periodic quantity is an oscillating quantity whose values recur for certain increments of the independent variable.

Sound - (1) Sound is an oscillation in pressure, stress, particle displacement, particle velocity, etc., in a medium with internal forces (e.g., elastic, viscous), or the superimposition of such propagated oscillations. (2) Sound is an auditory sensation evoked by the oscillation described above.

Sound Absorption - Sound absorption is the change of sound energy into some other form, usually heat, in passing through a medium or on striking a surface.

Sound Level (SL) - Sound level is a weighted sound pressure level, obtained by the use of metering characteristics and the weightings A,B, or C as specified in the American National Standard Specification for Sound Level Meters, ANSI-S1.4-1971. The weighting employed must be stated.

Sound Pressure - The sound pressure at a point is the total instantaneous pressure at that point in the presence of a sound wave minus the static pressure at that point.

Sound Pressure Level (SPL) - The sound pressure level, in decibels, of a sound is 20 times the logarithm to the base 10 of the ratio of the pressure of this sound to the reference pressure. The reference pressure must be stated. The following reference pressure is in common use for measurements concerned with hearing and with sound in air and liquids: $2 \times 10^{-5}$ N/M$^2$. Unless otherwise explicitly stated, it is to be understood that the sound pressure is the effective (rms) sound pressure.

Spectrum - (1) The spectrum of a function of time is a description of its resolution into components, each of different frequency and (usually)

of different amplitude and phase. (2) Spectrum is also used to signify a continuous range of components, usually wide in extent, within which waves have some specified common characteristic; e.g., "audio-frequency spectrum."

## Adding Sound Pressure Levels

Since the decibel is a logarithmic unit, sound pressure levels from different, independent sources cannot be combined by simple addition. The correct procedure is to convert the sound pressure level to ratios of sound intensities add the ratios, and then reconvert to decibels. This procedure is given by the equation:

Effective sum of SPL, $SPL_2$, . . . ., and $SPL_n$ =

$$10 \log \left[ 10^{\frac{(SPL_1)}{10}} + 10^{\frac{(SPL_2)}{10}} + \ldots 10^{\frac{(SPL_n)}{10}} \right]$$

For example:

where

$SPL_1$ = 95 dB and $SPL_2$ = 94 dB

Then the effective sum is:

= $10 \log \left[ 10^{9.5} + 10^{9.4} \right]$

= $10 \log \left[ (3.16 + 2.50) (10^9) \right]$

= $10 \log \left[ 5.66 \times 10^9 \right]$

= $10 (0.75 + 9.0)$

= 97.5 dB

This is a time-consuming procedure, hence graphs and tables are available to aid in the addition of decibels.

## Response of the Ear

Upon inspection of the definition of sound pressure level, it is evident that there is no reference to frequency. In actuality, the ear does not show equal response to all frequencies, and in fact, it is more sensitive to the middle frequencies than to the low or high ones. Studies have been made which determine the sound pressure levels of simple tones at various frequencies which sound just as loud to an observer as a 1000 Hz tone of a particular SPL. The results of such comparisons are given as equal loudness curves in Figure 1. The number of each curve, loudness level in phons, is the SPL of the 1000 Hz tone used for comparison in determining the curve.[3]

## Measurement Scales

These equal loudness contours have been taken into account in the standardization of several frequency weighting networks which are included on most sound measuring equipment. The frequency characteristics of these networks are given in Figure 2. The A scale corresponds approximately to the 40-phon equal loudness contour, the B-scale corresponds to 70-phons, and the C-scale corresponds to the 100-phon contour. With these weighting networks, which modify sound pressure level to approximate the ear's response, the term to be used is sound level, and the weighting used must always be stated. ("The A-sound level is 86 dB" or "86 dBA" are appropriate expressions.) The reference pressure is $2 \times 10^{-5}$ N/M$^2$).

The A scale is commonly used in measuring noise to evaluate its effect on people, and the A-weighted sound level is considered an adequate number to indicate or rate the hazard of a certain noise. Explanation of these measurements is given in Part IV.

## Correction of Original Baseline Audiograms for Age

To determine whether there has been a significant change in an employee's hearing due to noise exposure by comparing an audiogram taken since the original baseline audiogram with that audiogram it is necessary to make a correction for difference in age.

The best way to make this correction is to use data from a non-noise exposed group from the same area tested in the same manner as the group under consideration. Quite often this is not possible; therefore, it is necessary to establish an age correction that can be used universally.

Data are presented in Table B-1 of Appendix B for non-noise exposed males from studies by NIOSH, which are described in Part VI. These data represent workers who received no significant noise exposure (< 80 dBA-Slow) on the job, off the job or during military service, have no history of ear problems, and from otoscopic examination appear to have normal ears. The hearing study of the National Health Survey,[5] represents a random sample of the United States adult population tested during 1960-1962. No screening was done in this study to exclude those with significant noise exposure or questionable medical histories. Current Eastman Kodak Company[6] hearing data and the ISO Draft Proposal for hearing levels of non-noise exposed people at various ages are two studies which excluded members of the population with otological abnormalities or significant noise exposure.

The data from these four studies with respect to differences in hearing level from age 20 are quite similar. However, the greater changes apparent in the National Health Survey data at the upper frequencies could be expected because this population was not screened for significant noise exposure.

Thus, to provide a uniform correction, tables B-1 and B-2 (Appendix B) derived from the NIOSH data, will be used as specified in the standard.

## Conversion of Octave Band Levels to dBA Levels

When the octave-band sound pressure levels of a noise have been measured it is often desirable to compute the A-weighted sound pressure level from them. This can be done as follows:

1. From each octave band level, subtract (or add) the A-weighting correction value shown in Table III, corresponding to the frequency of the octave band.

2. Let $K_1$, $K_2$,. . ., $K_N$ denote the corrected octave band levels obtained from 1 above. The dBA level $L_A$ is then $L_A = 10 \log S$ where $S =$ antilog $(K_1/10)$ + antilog $(K_2/10)$

$$+ \ . \ . \ . \ + \text{antilog } (K_N/10)$$

(logarithms are base 10)

This method is quite accurate although it does involve some approximation.

## Calculation of dBA Reduction R for an Ear Protector

Calculation of dBA reduction R for ear protectors can be done as follows:

1. When the octave band levels of the noise are known: If the dB attenuation levels of the ear protector were known for each octave band, then the dBA reduction of the ear protector could be determined by subtracting these attenuation levels from the original octave band noise levels, and then calculating the dBA level of the resulting attenuated octave band levels using the method described in the previous section. One would then subtract this dBA level from the original dBA level to obtain the dBA reduction.

However, the American National Standard for Measurement of Real-Ear Attenuation of Ear Protectors at Threshold, ANSI Z24.22 (1957), prescribes pure-tone tests at 125, 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz. We shall also assume that the 4000 Hz octave band attenuation level can be obtained by averaging the pure tone attenuation levels at 3000 and 4000 Hz, and that the 8000 Hz octave band attenuation level can be obtained by averaging the pure tone attenuation levels at 6000 and 8000 Hz.

This method has been formulated concisely in Appendix A of the Recommended Noise Standard, also including a factor of 10 which is to be subtracted to account for possible noise spectrum irregularities and noise leakage which might be caused by long hair, safety glasses, head movement, or various other factors. It ignores noise in the 31.5 Hz, and 16,000 Hz bands, but these rarely contribute substantially to the dBA level.

2. When the octave band levels are not known it is assumed that the noise has a uniform "pink" spectrum, i.e., equal levels in each octave band. This type of noise is representative of "average" occupational noise, and the error introduced by making this approximation is usually small. The assumption results in a simplified formula for calculation, as presented in Appendix A of the recommended Noise Standard. It is recommended, however, that the more exact method described in (1) above be used whenever octave band noise levels are available.