A-weighted equivalents of permissible ambient noise during audiometric testing

M. C. Killion

Industrial Research Products, Elk Grove Village, Illinois 60622

G. A. Studebaker.

City University of New York, New York, New York 10036
(Received 19 September 1977; revised 31 January 1978)

Using the relative octave band levels obtained by Botsford [Sound Vib. 3, 16–28 (1969)] for various noise spectra, it is possible to calculate the *A*- and *C*-weighted sound levels of typical noises just meeting the requirements of ANSI S3.1-1977. Such a calculation indicates an *A*-weighted sound level of approximately 15 dB is required to meet the maximum permissible octave band levels for testing at audiometric zero in the ears-not-covered condition. For the average typical curves shown by Botsford, the calculated *A*-weighted sound levels range from 14.0 to 16.5 dB. For the case where the ear is covered by an earphone mounted in an MX-41/AR cushion, an *A*-weighted level of 22 dB or less appears to be required. For applications requiring determination of hearing threshold down to the conventional upper limit of "normal hearing," (25 dB HL) the corresponding *A*-weighted noise levels are 40 dB for sound field testing and 47 dB for earphone testing.

PACS numbers: 43.66.Cb, 43.66.Yw, 43.66.Sr

Botsford (1969) studied the octave band analyses of 953 noises which he group according to the difference ($C-A$) between the calculated A- and C-weighted sound levels. He then calculated the Perceived Noise Levels, Speech Interference Levels, Damage-Risk Criteria, etc., corresponding to the octave band analyses of the individual noises. These calculations denomstrated that the A-weighted sound level meter readings could provide an accurate gauge of the human response to most noises. Botsford (1973) later presented curves of the average relative octave band levels corresponding to the noises in each of seven $C-A$ groupings.

Following a similar line of reasoning, it is possible to calculate the A- and C-weighted sound levels corresponding to each of Botsford's curves after the values have been adjusted in level to just meet the maximum allowable octave band level requirements of the new

 0001-4966/78/6305-1633$00.80

standard for audiometer room noise (ANSI *S*3.1-1977). Figure 1 illustrates the procedure with a range of noise types likely to be encountered around an audiometric test facility. The solid line represents a smooth curve drawn through the maximum octave band levels permissible when testing at 0-dB hearing threshold level under the ears-not-covered condition. The other curves represent the average octave band levels for Botsford's *C–A* groupings of 0, 2, 5, 10, and 15 dB. In each case, the vertical position of the curve has been adjusted to just meet but not exceed the curve representing maximum permissible octave band levels. Table I lists the calculated *A*- and *C*-weighted levels for each of the noises. Note that the total range of the *A*-weighted noise levels is less than 3 dB. It is apparent that an *A*-weighted noise level below 15 dB will generally meet the requirements of the new standard for the ears-not-covered (field audiometry or unoccluded bone conduction testing) condition.

A similar procedure was carried out for the condition where the ears are covered with an earphone mounted in an MX-41/AR cushion. The results are shown in Table II. In this case, there is a substantially larger spread of values but it appears that an *A*-weighted sound level of 22 dB or less (or a *C*-weighted level of 30 dB or less) will generally insure an adequate room for earphone audiometry. Apparently the *C* scale of the sound-level meter would be more useful for assessing ambient noise during earphone audiometry. This comes about because the noise attenuation of the earphone cushion is greatest in the high-frequency region where the *A*-weighted response of the sound-level meter is greatest.

The maximum allowable levels in the new standard were designed so that "the average normal hearing listener will produce a threshold free of significant effect from the ambient noise." The allowable effect in this case was a 1-dB increase in threshold above the accepted reference hearing threshold levels. In many cases where the audiometer is to be used for screening

TABLE I. Allowable room-noise levels for "ears-not-covered" condition.

C–A (dB)	Allowable *A*-weighted level (dB)	Allowable *C*-weighted level (dB)
0	14	14
2	14.4	16.4
5	16.5	21.5
10	16.2	26.5
15	16.5	31.5

purposes or the selection of hearing aids, accurate threshold determinations may not be required below 25-dB hearing threshold level. In such cases, the standard specifies "the maximum allowable ambient noise levels for test conditions which exceed the reference threshold levels may be calculated by arithmetically adding the amount by which the minimum acceptable test hearing threshold levels exceed the reference hearing threshold levels at each test frequency." If the minimum acceptable test hearing threshold levels are set at 25 dB, i.e., at what is normally considered the upper limit of "normal threshold," then the allowable *A*-weighted noise levels become approximately 40 dB*A* and 47 dB*A* for the ears-not-covered and ears-covered conditions, respectively.

Sound level meters of at least type 2 quality (ANSI S1.4 1971) may be used instead of octave or one-third-octave band analyzers to quickly and routinely check the acceptability of an office, classroom, or closet for threshold determinations *at the time of use*.

However, it is emphasized that the use of a sound-level meter for this purpose involves the assumption that the background noise has a reasonably smooth spectrum and that it falls generally within the range of typ-

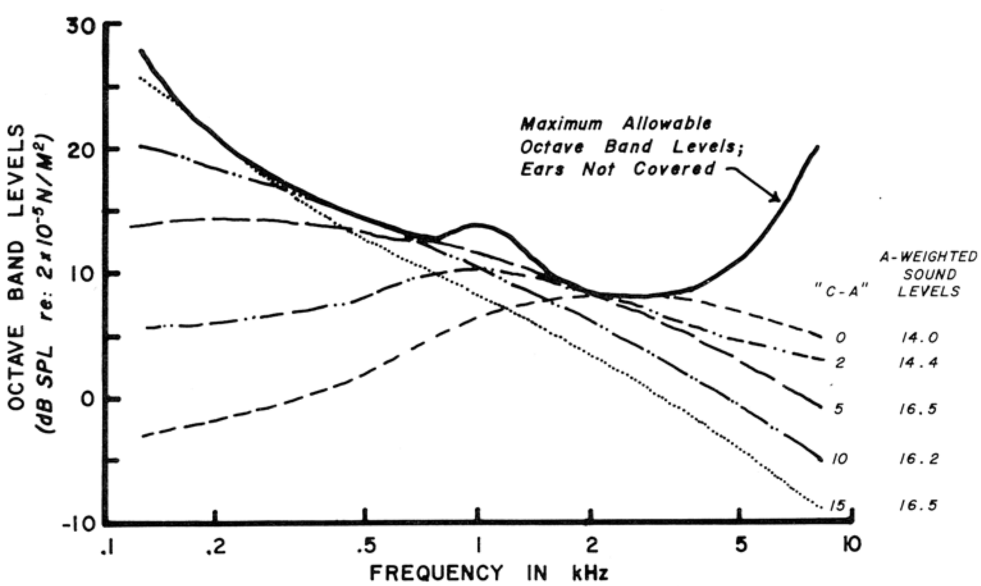

FIG. 1. Estimation of allowable *A*-weighted ambient noise levels for audiometric testing to O-dB HTL with uncovered ears.

TABLE II. Allowable room-noise levels for TDH-39/MX-41 AR earphone audiometry.

$C-A$ (dB)	Allowable A-weighted level (dB)	Allowable C-weighted level (dB)
0	31.7	31.7
2	27.2	29.2
5	24.5	29.5
10	21.7	31.7
15	21.1	36.1

ical noises as illustrated in Fig. 1. Botsford (1973) states that "These curves can be used to predict the levels of five of eight octave bands within 3 dB for two-thirds of all real noises." This statement indicates that while most environmental noises fall within this range, some do not. In at least half of all cases the effect will be to cause the sound-level-meter reading to read too high. In the remainder, when the sound-level meter underestimates the masking that might be produced by the noise, the error will usually be caused by a concentration of energy in a particular frequency region. In many cases, this energy concentration will be audible as a whistle, screech, hum, or a noise with an identifiable pitch. Such audible concentrations indicate the need for a more detailed narrow-band analysis. If this is not possible, it should be determined whether pure tones with pitches similar to that of the ambient signal are audible to the normal hearing listener at the criterion threshold level in that environment.

All measurements made in bandwidths wider than a critical band are subject to errors caused by concentrations of energy within particular regions in the analysis band width. The magnitude and the likelihood of occurrence of this potential error increases with the analysis bandwidth. Nevertheless, it is felt that the method described herein is adequate for many routine applications such as screening for possible test locations, monitoring test locations where noise levels vary over time, or assessing the adequacy of locations of convenience or necessity such as homes, offices, nursing homes, school rooms, etc., for certain noncritical hearing testing or when no alternatives exist.

The authors believe the following statement is justifiable:

> An ambient noise level of less than 40 dBA will, in most instances, allow accurate sound-field threshold determination down to the upper limit of "normal threshold," i.e., down to a 25-dB hearing level, at the audiometric frequencies of 125–8000 Hz. This criterion should only be applied when no prominent tonal-like components (whistle, screech, hum, etc.) of the noise are audible. A room just meeting the 40-dB A limit may allow accurate thresholds to be obtained below 25-dB hearing level at some frequencies, depending on the exact spectral characteristics of the noise, but the determination of that fact would require a more sophisticated, narrow-band noise analysis. With unusual distributions of the ambient signal spectrum, thresholds in some frequency region(s) may be elevated above those predicted. Should audible whistles, screeches, hums, or tonal-like noise suggest the possibility of such an ambient signal, a more detailed analysis should be performed, or the thresholds of normal hearing persons should be ascertained in the presence of that signal.

When earphone audiometry is to be used, the same statement would apply, changing the 40 dBA to 47 dBA (or 55 dBC) in each case.

As a check on these results, the authors have calculated the hearing loss—with reference to the ISO R226-1961 recommended values for normal minimum audible field—corresponding to the average 43-dBA residential noise level found by Seacord (1940). The average room-noise spectrum levels (which most nearly correspond to Botsford's $C-A=5$-dB curve) measured by Hoth (1941) and reported by Fletcher (1953), and the Fletcher critical band levels given in ANSI S1.13-1971, were used for these calculations. The results of these calculations indicate that the masking effect of typical residential room noise produces a nearly uniform 23-dB hearing loss across the 250–4000-Hz speech frequencies. Thus, the average hearing loss typically produced by the masking effect of a 40-dBA room noise would be 20 dB. Similarly, the calculated loss produced by a typical 40-dBA noise with $C-A=10$ dB (see Fig. 1) ranged between a minimum of 17 and 25 dB across the frequencies from the 250 to 4000 Hz, with an average value of 22 dB.

Subtracting 15 dB from the A-weighted noise level in a room provides a rough estimate of the *maximum* threshold elevation produced by that noise. Alternately, subtracting 20 dB produces a rough estimate of the *average* threshold elevation produced by that noise. The latter is the same rule of thumb suggested earlier by Killion (1976) for assessing the effect of microphone noise levels.

ANSI (1971a), "Specification for Sound Level Meters," S1.4-1971 (Am. Nat. Stand. Inst., New York).
ANSI (1971b), "Methods for Measurement of Sound Pressure Levels," S1.13-1971 (Am. Natl. Stand. Inst., New York).
ANSI (1977), "Criteria for Permissible Ambient Noise During Audiometric Testing," S3.1-1977 (Am. Nat. Stand. Inst. New York).
Botsford, J. H. (1969), "Using Sound Levels to Gauge Human Response to Noise," Sound Vib. 3 (10), 16–28.
Botsford, J. H. (1973), "How to Estimate dBA Reduction of Ear Protectors," Sound Vib. 7 (11), 32–33.
Fletcher, H. (1953), *Speech and Hearing in Communication* (Van Nostrand, Princeton, NJ), p. 105.
Hoth, D. F. (1941), "Room noise spectra at subscriber's telephone locations," J. Acoust. Soc. Am. 12, 499–504.
Killion, M. C. (1976), "Noise of Ears and Microphones," J. Acoust. Soc. Am. 59, 424–433.
Seacord, D. F. (1940), "Room noise at subscriber's telephone locations," J. Acoust. Soc. Am. 12, 183–187.