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DEVELOPMENT OF A NEW ANSI STANDARD FOR ASSESSMENT OF COMBINED NOISE ENVIRONMENTS

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1. INTRODUCTION

Since the early 1970s, many agencies within the United States of America have used day-night average sound level (DNL) as the fundamental descriptor for environmental sound. ANSI S12.9 Part 1 [1] defines and describes DNL and Part 2 [2] describes its measurement. ANSI S12.40 [3] further describes DNL and its relation to long-term land use planning. Several federal agencies including the Environmental Protection Agency, the Department of Defense, the Department of Transportation and the Department of Housing and Urban Development reconfirmed the use of DNL for planning purposes with respect to aircraft noise in 1993 [4]. In much of the rest of the world, equivalent level is used rather than DNL.

The seminal paper by Schultz [5] demonstrated the efficacy of DNL for estimating the annoyance resulting from the noise from road traffic, railroads, aircraft and some industrial sites. A recent paper [6] reconfirmed the Schultz relationships for these sources, although some data indicate that for the same DNL, aircraft noise elicits a greater annoyance response than does road traffic and railroad noise. Nevertheless, the current practice is to use DNL equally for all of these noise sources either singly or for two or more in combination.

DNL also has been used for types of noises that were not included in the Schultz data base or in its subsequent analysis. These additional types of noises include sounds with special characteristics, such as impulsiveness, rapid onset, dominance by pure tones or low-frequency energy. Scientific literature demonstrates that these sounds may be assessed by the basic DNL methodology provided that suitable adjustment factors or penalties are applied to their measured or predicted DNLs. However, there are no attitudinal surveys that demonstrate that the adjusted DNL values of these sounds with special characteristics can be combined with each other or with the traditional sounds studied by Schultz to obtain an overall prediction of annoyance within a stated accuracy. Nevertheless, at this time an adjusted DNL methodology offers the most widely accepted and consistent approach to the prediction of annoyance to sounds of varying characteristics.

This Standard provides the necessary adjustments for sounds with special characteristics so that they can be described in an annoyance-assessment system that is based on the DNL methodology. In this system the adjusted sounds are termed adjusted sound level, adjusted sound exposure, and adjusted day-night sound exposure. Traditional sounds such as highway noise, are evaluated directly as sound exposure without adjustment or penalty. The annoyance-assessment system in this Standard describes a noise environment that may consist of a variety of noises, both traditional and sounds with special characteristics. The description is in terms of quantities based upon adjusted sound exposure by means of a method that is directly analogous to the DNL method used for describing an environment of traditional sounds.

2. SCOPE OF DRAFT STANDARD

This Standard specifies a method to assess potential human annoyance to outdoor long-term noise from any and all types of environmental sounds from one or more discrete or distributed sound sources. The sound sources may be separate or in various combinations. Application of the method of the Standard is limited to areas where people reside and to related long-term land uses.

This Standard does not address the affects of short term exposure of people to intrusive sound in areas such as parks and wilderness regions, nor does it address other affects of noise such as sleep disturbance or health effects. This Standard does not provide a method to assess the annoyance from other short-term, infrequent sources of sound such as outdoor concerts or short-term construction activities.

This Standard introduces the application of new descriptors, adjusted sound exposure and adjusted sound exposure level, which are closely related to sound exposure and sound exposure level, respectively. The new descriptors are intended to facilitate the assessment of the wide range of sounds covered by the scope of the Standard, allowing for consideration, when necessary, of the effect of low-frequency content, onset rate, tonality or impulsivity.

3. DEVELOPMENT OF THE DRAFT STANDARD

Day-night level (or equivalent level) is calculated from the total sound exposure on the average day. For the average day, each event, *i*, such as an aircraft flyby generates a (predicted or measured) A-weighted sound exposure (ASE_i). The sound exposures of each aircraft flyby are summed with the sound exposure of nighttime events multiplied by a factor of 10. This total day-night sound exposure (DNSE) is converted to DNL by dividing by 86,400 (the number of seconds in a day) and converting to a level by taking 10 times the common logarithm of the result. Currently, if we have two sources such as motor vehicle and aircraft, then we find the total DNSE, on the average day by adding together all the sound exposures of each vehicle and aircraft. We compute:

$$DNSE = \sum_{i=1}^{N_{day}} ASE_i + 10 \sum_{j=1}^{N_{night}} ASE_j \qquad \text{[Eq. 1]}$$

and

$$L_{dn} = 10 \lg[(1/24{*}3600)(DNSE/SE_o)] \qquad \text{[Eq. 2]}$$

where SE_o is the reference sound exposure of 400 μ-pascal-squared seconds (Pa^2s).

The key factor here is that we sum the sound exposures of individual events. And it is the individual event sound exposures that should receive the penalties. For example, there is a Draft International Standard (DIS) which amends ISO 1996 Part 2 in terms of impulse penalties. The DIS uses two levels of adjustment or penalty which depend on the character of the impulsive sound. When measurable, these penalties are added to the A-weighted sound exposure levels of the individual impulses. Thus, differing impulsive sound may receive differing adjustments or penalties in the same calculation. Further, if some of the impulses would be inaudible, then these impulses receive no penalty. The adjustments or penalties are only added to the audible impulsive sounds.

Again, the key factor here is that we sum the sound exposures of individual events. To combine noise environments, we should add (or not add) the adjustment to the individual single event sound exposures as they are included into the sum rather than just adding the adjustment to the partial sum for some category of sound.

The general form of the equation is:

$$DNSE = \sum_{i=1}^{N_{day}} (ASE_i \times \mathcal{P}_i) + 10 \sum_{j=1}^{N_{night}} (ASE_j \times \mathcal{P}_j) \qquad \text{[Eq. 3]}$$

where $\mathcal{P}_i$ is the adjustment which multiplies the ith event. (Note: $\mathcal{P}_i$ *multiplies* ASE_i. In decibels one would *add* the penalty or adjustment $P_i = 10 \lg(\mathcal{P}_i)$. The adjusted sound exposure level, L_{AEi}' would be given by the measured or predicted event sound exposure level, L_{AEi} *plus* P_i.

This method of addition allows for maximum flexibility. When there is no adjustment, the ASE's just add; where there is a constant adjustment, the ASE's add with an adjustment factor *multiplier* which is absolutely equivalent to *adding* the logarithmic adjustment to the partial DNL for that source; and where a constant adjustment is not appropriate, one can incorporate an adjustment for a specific source which may be dependent on the measured sound exposure.

4. THE PROPOSED ADJUSTMENT FACTORS

Sound exposure (or the corresponding sound exposure level) is the fundamental descriptor for characterizing the sound from individual sources. For individual single-event sounds such as single impulses, sound exposure is directly measured or predicted for the sound-producing events under consideration. For a continuous source of sound such as a cooling tower fan, the time-average sound is measured or predicted for the time period of interest and the sound exposure is calculated as the product of the time-mean-square sound pressure in pascals and the duration in seconds of the time period of interest.

The frequency-weighting A is used for all sources of sound except high-energy impulse sound for which the frequency-weighting C is used.

Adjusted sound exposure is the quantity used in this Standard to describe both traditional sounds and sounds with special characteristics with respect to their potential relative annoyance. It is calculated from sound exposure with an adjustment that depends on the type of sound. For sounds without special characteristics, adjusted sound exposure is numerically equal to the A-weighted sound exposure in pascals-squared seconds. For sounds with special characteristics, the calculation of adjusted sound exposure from sound exposure for such sounds is performed as follows: For any sound except high-energy impulsive sound or sounds having strong low-frequency content, adjusted sound exposure N_{Ei} is given by the sound exposure multiplied by the adjustment factor K for that sound. That is:

$$N_{Ei} = K_j S_{AEi} \qquad \text{[Eq. 4]}$$

where S_{AEi} is the sound exposure for the *i*th event and K_j is the adjustment factor for the *j*th type of sound as given in Table 1. Methods to calculate adjusted sound exposure for high-energy impulse and low-frequency sound are given in annexes C and D of the proposed standard, respectively.

The adjusted total sound exposure, denoted by $N_{ET(period)}$, during a time period of interest such as daytime, is the sum of the adjusted sound exposures N_{Eij} from each individual event *i* of I events; for each source of sound *j* of J sources during the stated time period. This sum includes both sounds with special characteristics and traditional sounds without special characteristics. That is:

$$N_{ET(period)} = \sum_{i=1}^{I} \sum_{j=1}^{J} N_{Eij} \qquad \text{[Eq. 5]}$$

NOTES

1 The stated time period may be for any length such as one daytime period for one day or for any number of days up to 365 days of a year. Furthermore, the adjusted sound exposure N_{Eij} for the *i*th event may be for any one source *j* or a combination of sources.

2 In Eq. (5), sounds without special characteristics are included with an adjustment factor multiplication value of 1 as given in Table 1.

5. ACTIONS

As of the writing of this paper, this proposed Standard has been balloted by the ANSI S12 committee and all 3 negative votes to date are minor, largely editorial, and are being resolved. The revised proposed Standard will being sent to the ANSI S12 committee for subsequent processing and printing as an American National Standard.

6. REFERENCES

[1] ANSI, **(1988).** "*AMERICAN NATIONAL STANDARD Quantities and Procedures for Description and Measurement of Environmental Sound. Part 1*," ANSI S12.9-1988/Part 1 (R 1993), (Acoust. Soc. of Am., New York).

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[3] ANSI, **(1990).** "*AMERICAN NATIONAL STANDARD Sound Level Descriptors for Determination of Compatible Land Use*," ANSI S12.40-1990 (R 1996) (Revision of ANSI S3.23-1980), (Acoust. Soc. of Am., New York).

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[6] Finegold, L.S., *et. al.*, **(1994).** "Community annoyance and sleep disturbance: Updated criteria for assessing the impacts of general transportation noise on people;" *Noise Control Eng. J.*, **42**(1), 25-30, Jan-Feb 1994.

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Table 1. Adjustment factors for assessment of all types of sounds

	Sound Source Type	K_j Symbol	Value	10 lg(K_j), dB	Condition
1	traditional sounds (e.g., road traffic)	K_N	1	0	--
2	highly impulsive	K_I	16	12	--
	regular impulsive	K_I	3	5	--
	tonal	K_I	3	5	--
	rapid onset rate R	K_R	1	0	R < 15 dB/s
			$10^{1.1\,lg(R/15)}$	11 lg(R/15)	15 ≤ R <150 dB/s
			12.6	11	R ≥ 150 dB/s
	high-energy impulsive		--	--	see annex C
	strong low-frequency content		--	--	see annex D

NOTES

1 Each adjusted sound exposure N_{Eij} is calculated from its corresponding sound exposure level L_{AEij} according to:

$$N_{Eij} = K_j\,10^{0.1(L_{AEij} - 94)} \qquad \text{[Eq. 6]}$$

2 Each adjusted sound exposure level L_{NEij} is calculated from its corresponding sound exposure level and adjustment factor K_j by:

$$L_{NEij} = L_{AEij} + 10\,\lg(K_j) \qquad \text{[Eq. 7]}$$

3 If sounds are not audible at the location of interest, then the concepts of clause 5 apply and the adjusted sound exposure for these sounds should not be included in the total.

4 ANSI S12.9 Part 3 provides a method to identify sounds with tonal content.

5 Normally, the onset rate is measured. Annex E provides an approximate method to calculate the onset rate for low flying aircraft.

6 If impulsive sounds occur at a rate greater than about 30 per second then the sounds usually are not perceived as distinct impulses and no adjustment factor should be applied. However, if the rate is regular and greater than 30 per second, then a tone will be perceived and a tonal adjustment factor may be required. If the rate is irregular and greater than 30 per second then the impulsive sounds will appear to merge into a broadband noise-like sound and no adjustment factor should be applied.