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Standard Guide for Selection of Environmental Noise Measurements and Criteria[1]

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1. Scope

1.1 This guide covers many measurement methods and criteria for evaluating environmental noise. It includes the following:

1.1.1 The use of weightings, penalties, and normalization factors;

1.1.2 Types of noise measurements and criteria, indicating their limitations and best uses;

1.1.3 Sources of criteria;

1.1.4 Recommended procedures for criteria selection;

1.1.5 A catalog of selected available criteria; and

1.1.6 Suggested applications of sound level measurements and criteria.

1.2 *Criteria Selection*—This guide will assist users in selecting criteria for the following:

1.2.1 Evaluating the effect of existing or potential outdoor sounds on a community;

1.2.2 Establishing or revising local noise ordinances, codes, or bylaws, including performance standards in zoning regulations; or

1.2.3 Evaluating sound indoors that originated from outside sources.

1.3 *Reasons for Criteria*—This guide discusses the many reasons for noise criteria, ways sound can be measured and specified, and advantages and disadvantages of the most widely used types of criteria. The guide refers the user to appropriate documents for more detailed information and guidance. The listing of specific criteria includes national government regulatory requirements. Users needing further general background on sound and sound measurement are directed to the books listed in the References section.

1.4 *Criteria in Regulations*—Certain criteria are specified to be used by government regulation, law, or ordinance for specific purposes. Ease of enforcement and cost impact on government are considerations for these criteria. They may not be the most appropriate criteria in some circumstances. This guide will discuss the limitations of these criteria.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 634 Terminology Relating to Environmental Acoustics[2]

E 966 Guide for Field Measurement of Airborne Sound Insulation of Building Facades and Facade Elements[2]

E 1014 Guide for Measurement of Outdoor A-Weighted Sound Levels[2]

E 1503 Test Method for Conducting Outdoor Sound Measurements Using a Digital Statistical Analysis System[2]

2.2 *ANSI Standards:*[3]

ANSI S1.4 American National Standard Specification for Sound Level Meters

ANSI S1.11 American National Standard Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters

ANSI S1.13 American National Standard Measurement of Sound Pressure Levels in Air

ANSI S3.1 American National Standard Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms

ANSI S3.4 American National Standard Procedure for the Computation of Loudness of Noise

ANSI S3.14 American National Standard for Rating Noise with Respect to Speech Interference

ANSI S12.4 American National Standard Method for Assessment of High-Energy Impulsive Sounds with Respect to Residential Communities

ANSI S12.7 American National Standard Methods for Measurement of Impulse Noise

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[2] *Annual Book of ASTM Standards*, Vol 04.06.

[3] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

ANSI S12.9 American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound

2.3 *ISO Standards:*[3]

ISO 532 Acoustics—Method for Calculating Loudness Level

ISO 1996 Assessment of Noise with Respect to Community Response

ISO 1999 Acoustics—Determination of Occupational Noise Exposures and Estimation of Noise Induced Hearing Impairment

ISO 2204 Guide to the Measurement of Airborne Acoustical Noise and Evaluation of Its Effects on Man

2.4 *IEC Standard:*[4]

IEC Standard 804 Integrating Averaging Sound Level Meters

3. Terminology

3.1 *General*—This guide provides guidance for various measurement methods and criteria defined in other documents. Most basic terms are defined in Terminology C 634.

3.2 *Definitions of Terms Not Used in Other ASTM Standards:*

3.2.1 *community noise equivalent level (CNEL)*—see *day-evening-night average sound level*.

3.2.2 *day-evening-night average sound level*, L_{Fden}—where F is the frequency weighting (understood to be A if deleted), [*nd*], (dB), n—a time average sound level computed for a calendar day period with the addition of 4.77 dB to all levels between 7:00 pm and 10:00 pm, and 10 dB to all levels after 10:00 pm and before 7:00 am. A-weighting is understood unless clearly stated otherwise.

3.2.3 *day-night average sound level (DNL)*, L_{Fdn}—where F is the frequency weighting (understood to be A if deleted), [*nd*], (dB), n—a time average sound level computed for a calendar day period with the addition of 10 dB to all levels after 10:00 pm and before 7:00 am. A-weighting is understood unless clearly stated otherwise.

3.2.4 *loudness, (sone)*, *n*—that attribute of auditory sensation in terms of which sounds may be ordered on a scale extending from soft to loud. **ANSI S1.1**

3.2.5 *normalization*, *n—as applied to the evaluation of noise in communities*, the practice of adjusting a measured sound level to compare to criteria that are based on conditions different from those present at the time or location of the measurement.

3.2.6 *sound exposure level*—FSEL where the F denotes the frequency weighting (understood to be A if deleted), L_{FE} where the F denotes the frequency weighting (understood to be A if deleted), [*nd*], (dB), n—ten times the logarithm to the base ten of the ratio of a given time integral of squared instantaneous frequency-weighted sound pressure, over a stated time interval or event, to the product of the squared reference sound pressure of 20 micropascals and reference duration of one second.

3.2.7 *speech interference level, SIL*, L_{SI}, [*nd*], (db), *n*—one-fourth of the sum of the band sound pressure levels for octave bands with nominal mid-band frequencies of 500, 1000, 2000, and 4000 Hz. **ANSI S1.1**

3.2.8 *time above (s or min per h or day)*, *n*—the duration that the sound level or time-average sound level exceeds a corresponding specified level during a specified total measurement period. If sound level is used, then the time weighting shall be specified; if time-average sound level is used, then the measurement time interval for each sample shall be specified. The frequency weighting should be specified; otherwise, the A-weighting will be understood. The unit for time in the ratio shall be stated, for example, as seconds or minutes per hour or day. **ANSI S12.9**

3.2.9 *time-weighted average sound level, TWA*, [*nd*], (dB), *n*—an indicator of hearing damage risk during a workday of any length expressed as an equivalent 8 h steady level. The TWA is not always based on an energy-equivalent or 3 dB exchange rate. Pertinent regulations specify an exchange rate indicating the number of decibels considered to double hearing damage risk. Such regulations also may specify computation based on sampled measurements of the A-slow-weighted sound level, and a threshold level below which sound levels are not included in the computation of the TWA.

3.3 *Index of Terms*—The following commonly used terms are discussed in the sections referenced in this guide.

Term	Section
A-weighting	6.2
C-weighting	6.2
community noise equivalent level	8.5.3
day-evening-night average sound level	8.5.3
day-night average sound level	8.5.2
equivalent level	6.5 and 8.5.1
fast, time weighting or sound level	6.3
impulse, time weighting or sound level	6.3
loudness	8.11
maximum sound level	8.3
normalization	7.4
octave band, or 1/3 octave band	6.6 and 8.9
peak sound pressure level	6.4 and 8.4
percentile level	8.6
slow, time weighting or sound level	6.3
sound exposure level	8.5.4
speech interference level	8.10
time above	8.7
time average sound level	6.5 and 8.5.1
time-weighted average sound level	8.8

4. Significance and Use

4.1 *Evaluation of Environmental Noise*—Environmental noise is evaluated by comparing a measurement or prediction of the noise to one or more criteria. There are many different criteria and ways of measuring and specifying noise, depending on the purpose of the evaluation.

4.2 *Selection of Criteria*—This guide assists in selecting the appropriate criteria and measurement method to evaluate noise. In making the selection, the user should consider the following: purpose of the evaluation (compatibility, activity interference, aesthetics, annoyance, hearing damage, etc.); type of data that are available or could be available (A-weighted, octave-band, average level, maximum level, day-night level, etc.); available budget for instrumentation and manpower to obtain that data; and regulatory or legal requirements for the use of a specific

[4] Available from International Electrotechnical Commission (IEC), 3 Rue de Varembe, CH 1211, Geneva 20, Switzerland.

criterion. After selecting a measurement method, the user should consult appropriate references for more detailed guidance.

5. Bases of Criteria

5.1 Most criteria for environmental noise are based on the prevention of problems for people. However, there are criteria for evaluating effects on animals, physical damage to structures, or reduced utility of property. When selecting criteria to evaluate a situation, it is very important to recognize the many different problems that may be caused by the noise.

5.1.1 *Health Impacts*—Damage to human hearing is the best documented effect of noise on health, with the best established criteria. Damage depends on sound levels and exposure time. Most noise-induced hearing loss is due to exposure over several years. People are often annoyed by noise at a much lower level than that required to damage hearing. This annoyance causes stress that can aggravate some physical conditions. Criteria for preventing these problems are usually based on annoyance. Research has shown some physical reactions of the human body to sound.

5.1.2 *Speech or Communication Interference*—Speech communication is essential to the daily activities of most people. There are criteria for the background sound levels needed to allow such communication.

5.1.3 *Sleep Interference*—High levels of sound and changes in sound level affect the quality of sleep or awaken sleepers.

5.1.4 *Task Interference*—High sound levels can either hinder or improve the performance of a task. The effect depends on the nature of the task as well as the sound.

5.1.5 *Annoyance and Community Reaction*—Annoyance and community reaction are different effects. Annoyance is a personal reaction to noise. Community reaction is evidenced by complaints to authorities. Some people are annoyed but do not complain. Some people use noise as an excuse to complain when they are not annoyed directly by a sound. Often annoyance and reaction are related to speech or sleep interference, reduced environmental aesthetics, or the effect of these factors on the utility and value of property. Many of the criteria developed for noise in residential communities are based on survey studies of annoyance or on adverse community reaction directed to public officials.

5.1.6 *Aesthetics*—Certain quantitative criteria can be used to identify sounds that have been found to be aesthetically unpleasing. Often such sounds contain strong discrete tones or are otherwise unbalanced in spectral content. This makes them particularly perceptible and intrusive, especially if they are persistent. Spectral criteria are used to specify or evaluate the aesthetic quality of the sound present. Some criteria can be used to evaluate whether a sound is rumbly or hissy, or has a perceptible or prominent tone. Sounds that do not meet aesthetic quality criteria are sometimes restricted to numerically lower overall A-weighted sound levels.

5.1.7 *Land Use Compatibility*—Noise compatibility criteria have been developed for land-use planning. These are most useful in determining whether a certain type of development can be made compatible with existing noise. Care is necessary when applying these criteria to evaluate a new noise in an existing community that was developed without anticipation of the noise.

5.1.8 *Effects on Wildlife*—Research has established some effects of noise on wildlife. However, additional research is needed to establish appropriate criteria.

6. Basics of Sound Measurement

6.1 *Introduction*—Sound usually is measured with a sound level meter. The basic instrument usually includes a choice of both frequency and time weightings. Frequency weighting adjusts the relative strength of sounds occurring at different frequencies before the level is indicated by the meter. Time weighting determines the reaction of the meter to rapidly changing sound levels. Some meters can respond to the instantaneous peak level and store or hold the highest value. Basic characteristics and tolerances of meters are specified in ANSI S1.4. Many meters called integrating-averaging meters also include the ability to measure the time average sound level over a period. This capability is defined in IEC Standard 804. Meters may include filters to measure sound in specific frequency bands. Specifications for these are found in ANSI S1.11. A classification of the types of sounds, as well as basic procedures for taking sound pressure level measurements at a single point in space, are found in ANSI S1.13.

6.2 *Frequency Weightings*—Several frequency-weighting networks (filters) have been internationally standardized. These networks provide a better match between measured results and human perception. The two used most frequently are designated A-weighting and C-weighting.

6.2.1 A-weighting is the most commonly used. It is used when a single-number overall sound level is needed. Results are expected to indicate human perception or the effects of sound on humans. A-weighting accounts for the reduced sensitivity of humans to low-frequency sounds, especially at lower sound levels.

6.2.2 C-weighting is sometimes used to evaluate sounds containing strong low-frequency components. It was originally devised to approximate human perception of high-level sounds.

6.2.3 B, D, and E weightings also exist but are seldom used.

6.3 *Time Weighting*—Sound levels often vary rapidly. It is not practical or useful for a meter to indicate every fluctuation of sound pressure. When it is desired to record the variation in sound, the meter performs an exponential average time weighting that emphasizes the most recent sound. There are three meter time-weighting characteristics commonly used in sound measurements (slow, fast, and impulse). A time weighting is specified whenever used in a measurement.

6.3.1 The slow weighting is the most commonly used time weighting. It provides a slowly changing level indication that is easy to read and is often specified in regulations.

6.3.2 The fast weighting more closely responds to human perception of sound variation. It provides a faster response to the instrument's indicator to changing sound levels. Fast response is often used for short duration measurements such as motor vehicle drive-by tests.

6.3.3 The impulse weighting allows a faster rise in indicated level than the fast weighting but causes a slower decrease in indicated level than the slow weighting. Originally developed in Germany, it is used in Canada to regulate the noise of firearms and pest control devices and some industrial noises.

6.3.4 All of the above time weightings will yield the same result if the sound is steady and not impulsive. They will yield different maximum and minimum levels for varying sound levels.

6.4 *Peak Sound Pressure Level*—A peak indicator measures the true peak level of a very short duration signal. It is preferred over impulse weighting to measure sounds of less than 1 s, such as a gunshot or impact. It is not normally used to measure steady sounds or slowly varying sounds. A peak detector responds to the absolute positive or negative value of the waveform rather than its effective or "root mean square" value. Peak detectors can respond to a sound pulse and provide an accurate reading in less than 50 µs. In normal use, a peak measuring instrument will hold its indication for ease of reading until reset or will store it in a memory for later reference. Although there are certain applications where A or C frequency weightings are used, it is most common to use the peak level unweighted. (In order to minimize confusion, the term "peak" should never be used to describe the maximum level measured with fast or slow time weighting.)

6.5 *Time-Average Sound Level*—Sometimes it is desirable to measure the average sound present over a specified period. This time-average sound level is often called the equivalent sound level or equivalent continuous sound level. It is the steady sound level whose sound energy is equivalent to that of varying sound in the measured period. The frequency weighting should be specified. Otherwise, for overall sound levels, it is understood to be A-weighting. The time-average sound level should be measured directly using an integrating-averaging sound level meter. However, regulations or instrument limitations sometimes require the time-average sound level to be computed from individual measurements using fast or slow time weightings.

6.6 *Frequency Analysis*—Electronic filters can be used to separate sound into frequency bands so measurements can be made in specific frequency bands. It is then possible to measure only the sound in a given frequency band using any time weighting or the time-average sound level. For environmental noise, measurements are usually made in octave or one-third octave bands. Octave-band or one-third octave band data or criteria are understood to be unweighted unless it is clearly stated otherwise.

7. Adjustments to Sound Levels to Account for Conditions Influencing Human Response

7.1 *Introduction*—Many non-acoustical factors influence human response to environmental noise. Special measurements and criteria apply adjustments to the sound level for these factors.

7.2 *Time-of-Day Penalties*—Many people expect and need lower sound levels at night, primarily for sleep and relaxation. In most outdoor locations, ambient sound levels are lower at night. It is preferable to have lower limits for sound during normal sleeping hours, most commonly from 10:00 p.m. until 7:00 a.m. The difference between daytime and night limits in local ordinances for residential areas is usually 5 or 10 dB. For those criteria based on average levels over a period containing both day and night, a 10 dB penalty is commonly added to sound levels during the night period before computing the average level. In some cases an evening penalty of approximately 5 dB is also used.

7.3 *Discrete Tone and Repetitive Impulsive Noise Penalties*—Sounds that give the sensation of pitch are called discrete tones, and may occur by themselves or within other sounds. These can be particularly perceptible, intrusive, unpleasant, and annoying especially if persistent. The same is true of sounds consisting of repeated pulses less than a second apart, which are called repetitive impulsive noise. In such cases, it is common for local noise ordinances to specify that the objective criterion be 5 dB more stringent than would be the case if the sound character were broad-band and steady.

7.4 *Normalization*—Some criteria presume conditions that are not appropriate in all cases. When these conditions are not met, the measured level is adjusted or normalized for the different conditions before comparing it to the criterion. This is done by adding or subtracting 5 or 10 dB from the measured level for each factor different from the normal assumption. Table 1 shows typical adjustments suggested by the U.S. Environmental Protection Agency (EPA) (see Ref **(2)**).

8. Sound Measurements, Their Best Uses and Weaknesses

8.1 *Introduction*—There are many ways of measuring and specifying limits on sound. The most appropriate measurement method and criteria should be selected for a specific case. For a given measurement method, the appropriate criterion could be an absolute level or a change in level. For instance, speech interference occurs above some absolute level. However, a change in level may better reflect the impact of a new sound on the aesthetic quality of a community. This section describes several measurement methods on which criteria are based and discusses their strengths and weaknesses. Other factors in the selection of the best measurement method and criteria are discussed in Section 9.

8.2 *Level of Steady Sound*—Sometimes sound is steady, and the character or frequency content is not unusual. This sound is easily measured with simple instrumentation. Criteria may simply state that the sound not exceed some overall level, usually A-weighted. If the frequency content is critical to the function and acceptance of the sound, more complex criteria and measurements are necessary. The criterion should address the possibility that the sound may not be steady in environments where it should be.

8.3 *Maximum Sound Level of Time Varying Sound* (Symbol L_{max}. Additional subscripts may be used to denote frequency and time weighting.)—Some criteria state maximum sound levels not to be exceeded by time varying sounds when measured with a specified time weighting, fast or slow. This type of criterion is useful when sound above the specified level creates a problem for even a short time, especially if it is recurring. Maximum sound level limits are often used in combination with other criteria. Maximum sound level limits alone are insufficient for specifying community noise criteria. If set appropriately for short duration noise, maximum sound level limits are too high to limit continuous noises properly.