Designation: E1686 – 10

Standard Guide for Applying Environmental Noise Measurement Methods and Criteria[1]

This standard is issued under the fixed designation E1686; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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; or

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

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:*[2]

C634 Terminology Relating to Building and Environmental Acoustics

E966 Guide for Field Measurements of Airborne Sound Attenuation of Building Facades and Facade Elements

E1014 Guide for Measurement of Outdoor A-Weighted Sound Levels

E1503 Test Method for Conducting Outdoor Sound Measurements Using a Digital Statistical Sound Analysis System

2.2 *ANSI Standards:*[3]

ANSI S1.1 Acoustical Terminology

ANSI S1.4 Specification for Sound Level Meters

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

ANSI S1.11–1966 Specification for Octave, Half-Octave, and Third-Octave Band Filter Sets

ANSI S1.13 Measurement of Sound Pressure Levels in Air

ANSI S1.43 Specifications for Integrating-Averaging Sound Level Meters

ANSI S3.4 Procedure for the Computation of Loudness of Noise

ANSI S3.14 Rating Noise with Respect to Speech Interference

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

ANSI S12.7 Methods for Measurement of Impulse Noise

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[1] This guide is under the jurisdiction of ASTM Committee E33 on Building and Environmental Acoustics and is the direct responsibility of Subcommittee E33.09 on Community Noise.

Current edition approved Sept. 1, 2010. Published October 2010. Originally approved in 1995. Last previous edition approved in E1686–02. DOI: 10.1520/E1686-10.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

ANSI S12.9 Quantities and Procedures for Description and Measurement of Environmental Sound, Part 1
Part 2–Measurement of Long-Term, Wide-Area Sound
Part 3–Short Term Measurements with an Observer Present
Part 4–Noise Assessment and Prediction of Long-Term Community Response
Part 5–Sound Level Descriptors for Determination of Compatible Land Use
Part 6– Methods for Estimation of Awakenings Associated with Outdoor Noise Events Heard in Homes

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 exposure 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 61672 Electroacoustics-Sound Level Meters

2.5 *DIN Standard:*[5]

DIN 45692 Measurement technique for the simulation of auditory sensation of sharpness (in German)

3. Terminology

3.1 *General*—This guide provides guidance for various measurement methods and criteria defined in other documents. Most acoustical terms used in both this and other ASTM standards are defined in Terminology C634 along with their abbreviations and symbols for use in equations.

3.2 *Definitions of Terms Specific to This Standard:* The following terms are 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_{*den}*—where * is a letter denoting the frequency weighting (understood to be A if deleted), (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_{*den}*—where * is a letter denoting the frequency weighting (understood to be A if deleted), (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,—**SEL where * is a letter that denotes the frequency weighting (understood to be A if deleted), L_{*E} where * is a letter that denotes the frequency weighting (understood to be A if deleted), (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}, (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.

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. **, Part 1**

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

Term	Paragraph
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

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, comfort, annoyance, health effects, hearing damage,

[4] Available from International Electrotechnical Commission (IEC), 3 rue de Varembé, Case postale 131, CH-1211, Geneva 20, Switzerland, http://www.iec.ch.

[5] Available from Beuth Verlag GmbH (DIN-- DIN Deutsches Institut fur Normung e.V.), Burggrafenstrasse 6, 10787, Berlin, Germany, http://www.en.din.de.

etc.); type of data that are available or could be available (A-weighted, octave-band, average level, maximum level, day-night level, calibrated recordings including .wav files from which various measurements could be made, etc.); available budget for instrumentation and manpower to obtain that data; and regulatory or legal requirements for the use of a specific criterion. After selecting a measurement method, the user should consult appropriate references for more detailed guidance.

4.3 *Objective versus Subjective Evaluations*—The overall sound environment as perceived outdoors is often called a soundscape. Soundscapes have both objective (quantitative) and subjective (qualitative) attributes. This guide is limited to the objective measurement and evaluation of sound found outdoors though the criteria used may be influenced by qualitative factors. Current soundscape research involves evaluation methods and criteria that rely extensively on qualitative factors, both acoustical and non-acoustical, while including requirements for quantitative sound measurement. Two basic tenets of quantitative soundscape measurements are that the ambient sound at a location is comprised of a combination of specific acoustic events that can be measured individually and in combinations; and that the sounds should be measured using methods that represent the ways in which they are heard by people. (**1**)[6]

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. Sound-scape methods address aesthetic components of sounds and provide for comfortable or satisfying sounds in addition to preventing noise problems. (**1**)

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 including cardiovascular effects such as elevation of blood pressure, mean respiratory volume, intestinal irritation and endocrine system responses among others. Pyscho-social effects of noise including agitation, withdrawal, anxiety and depression among others have also been identified in the literature. (**2**, **3**, **4**)

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. See ANSI S12.9 Part 6.

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 *Noise Characteristics*—Certain quantitative criteria can be used to further restrict sounds that have been found to be particularity noticeable, intrusive or to increase perceived annoyance especially if persistent. Often such sounds contain strong discrete tones or are otherwise unbalanced in spectral content. 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. Other particularly noticeable sounds include information contained in speech or music as well as impulsive sounds from gunshots, bass music beats, hammering, etc. Such sounds are sometimes restricted to numerically lower overall A-weighted sound levels in ordinances and regulations. C-weighted limits or octave-band limits are sometimes used for sounds with strong low-frequency content that are also time variant such as music, but care must be used that such limits are not inappropriately applied to steady sounds when the problem is the time variation. When sound levels vary strongly from an average, such as with aircraft overflights or occasional heavy truck passbys, criteria that identify the variation such as "time above" or statistical counts of the number of events within certain ranges of maximum levels can be used. Measures attempting to evaluate for perceived annoyance may take into consideration such factors as loudness, the time of day, sharpness and the effect of time fluctuations of the sound including roughness and fluctuation strength.

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] The boldface numbers in parentheses refer to the list of references at the end of this standard.

5.1.9 *Preservation of Natural Quiet*—Some locations such as large park, wilderness, and rural areas are noted for the limited presence of man-made sounds. The preservation of such existing conditions is often an objective.

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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. Integrating-averaging meters also include the ability to measure the time average sound level over a period. Specifications for meters are provided in ANSI S1.4, ANSI S1.43, and IEC Standard 61672. 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 sound pressure 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. The Z-weighting defines the frequency limits of the previously non-standardized "flat" weighting.

6.3 *Exponential Time Weightings*—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 continuous variation in sound, the meter performs an exponential average process that emphasizes the most recently occurring sound. Three standard meter time-weighting characteristics are commonly used in sound measurements (slow, fast, and impulse). The exponential time weighting used in a measurement should always be stated.

6.3.1 "Slow" 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 "Fast" more closely responds to human perception of sound variation. It provides a more rapid response to changing sound levels. Fast response is often used for short duration measurements such as motor vehicle drive-by tests.

6.3.3 "Impulse" allows a faster rise in indicated level than the fast weighting but causes a slower decrease in indicated level than the slow weighting so that one can read the maximum levels. 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" (rms) value. Peak detectors can provide an accurate indication for brief transient sounds lasting 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 without the use of an exponential time weighing. However, regulations or instrument limitations sometimes require the time-average sound level to be computed from many 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 with any of the methods described above can be made in specific frequency bands. When frequency analysis is performed for environmental noise, measurements are usually made in standardized octave or one-third octave bands (ANSI S1.11). Octave-band or one-third octave band data or criteria are understood to be unweighted unless it is clearly stated otherwise. Frequency analysis cam be a useful diagnostic tool to characterize, identify, and quantify individual sources of sound.

6.7 *Time History Analysis*—Plots of the time history of sound variation can demonstrate the variability of sound level and serve as a tool in identifying, separating, and quantifying individual components of the overall sound that are varying with time. Time history and frequency analysis are sometimes combined on the same three-dimensional plot. These analyses are usually based on calibrated recordings of the sound.

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

7.1 *Introduction*—Many acoustical and 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 and Time-of-Week 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 nighttime 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 ANSI S12.9 Part 4 recommends a penalty of 5 dB for sound that occurs on weekend days.

7.3 *Penalties based on Sound Characteristics*—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. ANSI S12.9 Part 4 alternatively recommends adding 5 dB to the measured sound levels before comparing to normal criteria. ANSI S12.9 Part 4 also recommends a 12 dB penalty for highly impulsive sounds such as gunshots occurring at a rate up to 20 per s, a penalty up to 5 dB for aircraft noise and a penalty up to 11 dB for sounds with a rapid onset such as fast low-flying aircraft.

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 (**5**)). Similarly, ANSI S12.9 Part 4 provides ways to account for various background sound conditions and sound characteristics.

7.5 *Psycho-acoustical factors*—From a psycho-acoustical perspective, human response to sound can be positive (for example, pleasantness) or negative (for example, annoyance). Various psycho-acoustical quantities have been developed for characterizing separate sensations of sound. These quantities include but are not limited to loudness, pitch, subjective duration, sharpness, roughness and fluctuation strength. Only loudness (ANSI S3.4 and ISO 532) and sharpness (DIN 45692) have been defined in standards. Methods have been proposed that combine some of these quantities to evaluate for negative human response such as annoyance. However, as with the quantities themselves, these methods have not yet been incorporated into standards. (**6**)

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

TABLE 1 Corrections Added to the Measured Noise Level to Obtain Normalized Level

Type of Correction	Description	Amount Added to Measured Level in dB
Seasonal correction	Summer (or year-round operation)	0
	Winter only (or windows always closed)	−5
Correction for outdoor noise level measured in absence of intruding noise	Quiet suburban or rural community (remote from large cities and from industrial activity and trucking)	+10
	Normal suburban community (not located near industrial activity)	+5
	Urban residential community (not immediately adjacent to heavily traveled roads and industrial areas)	0
	Noisy urban residential community (near relatively busy roads or industrial areas)	−5
	Very noisy urban residential community	−10
Correction for previous exposure and community attitudes	No prior experience with intruding noise	+5
	Community has had some previous exposure to intruding noise, but little effort is being made to control the noise. This correction may also be applied in a situation where the community has not been exposed to the noise previously, but the people are aware that bona fide efforts are being made to control the noise.	0
	Community has had considerable previous exposure to the intruding noise, and the noise maker's relations with the community are good.	−5
	Community is aware that operation causing noise is very necessary and it will not continue indefinitely. This correction can be applied for an operation of limited duration and under emergency circumstances.	−10
Discrete tone or impulse	No discrete tone or impulsive character	0
	Discrete tone or impulsive character present	+5

discusses their strengths and weaknesses. Other factors in the selection of the best measurement method and criteria are discussed in Section 9. Further guidance on the use of the most common measures of overall sound in the outdoor environment, as discussed in 8.2–8.7, can be found in the ANSI S12.9 series of standards.

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. In modern usage this refers to the maximum instantaneous level observed using a specified time weighting such as fast or slow. Many older documents referring to limits on sound levels are actually referring to approximate average sound levels measured by procedures in ANSI S1.13 and earlier standards used before the advent of integrating-averaging instruments.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. Limits set appropriately for recurring short-duration sounds may be too stringent for a sound that occurs only once and is not repeated.

8.4 *Peak Sound Pressure Level* (Symbol L_{Pk}. An additional subscript may be used to denote frequency weighting.)—When sounds are identified as discrete events lasting much less than 1 s, such as individual gunshots, discrete musical notes or hammer blows, it is appropriate to use the peak level. Further guidance can be found in ANSI S12.7.

8.5 *Time-Average Sound Level and Variants*—The availability of instruments to measure the time-average sound level has made this a popular way to measure and specify criteria for nonsteady sounds. It is a preferred method of measuring, comparing, and specifying levels for sounds varying irregularly but by only a few decibels. It also can be used where the variation in level is large. Very loud short-duration events strongly influence the time-average level. A drawback to the use of energy equivalent measures is uncertainty about whether two sounds with the same energy equivalence are perceived to be equally loud or whether the average relates to the way sounds are actually perceived by people. While a steady sound of a given level may be perfectly acceptable, a sound with widely varying levels having the same time-average level may be unacceptable, or vice-versa. The perceived loudness of a series of events over a period may be different from the perceived loudness of a steady sound of the same energy equivalent average sound level over the same period. The time-average sound level has been used to characterize the long-term acoustical environment. However, people expect and need quieter sound levels during some parts of the day. Therefore, it is common practice to use night-time or evening penalties to compute modified time-average sound levels. The most familiar of these descriptors is the day-night average sound level. An advantage of the time-average sound level concept is that the expected levels can be calculated from databases for common sound sources without measuring every situation. The frequency weighting should be specified for all variants of time-average sound level. Otherwise, A-weighting is understood. Further guidance can be found in ANSI S12.1 Part I.

8.5.1 *Time-Average Sound Level* (Symbol L_*, where * is the measurement period. An additional subscript may indicate the frequency weighting. The name equivalent sound level, Symbol L_{eq}, and abbreviation LEQ are also commonly used.)—This is the actual energy-equivalent average sound level measured over a specified length of time. The time can be anywhere from less than 1 s to several years. The time-average sound level measured over a period from a few minutes to 1 h is often used in local noise ordinances. In such cases, it is common to specify a lower required level at night in residential areas. The time-average sound level is one method used by the U.S. Federal Highway Administration (FHWA) for evaluating highway noise. Time-average sound level has a clear advantage over a maximum level specification since most environmental sounds vary with time. A disadvantage is that a single number time-average sound level may disguise a wide variation in sound levels.

8.5.2 *Day-Night Average Sound Level* (Abbreviation DNL, with LDN commonly used, and Symbol L_{dn}. An additional subscript may indicate the frequency weighting.)—This variant adds 10 dB to all sound between 10:00 p.m. and 7:00 a.m. before computing the average level over a 24 h period. Day-night average sound level is used extensively for community land use planning purposes and in U.S. federal government criteria for funding housing and evaluating airport noise. It is the preferred method for these uses. An advantage of this type of criterion is the ease of calculating expected noise levels without actually measuring the specific situation. Day-night average sound level is measured or computed for a minimum period of 24 h or multiples thereof. It is most common to compute day-night average sound level as an annual average. Such long-term averages may not indicate problems that exist during only part of a year or even part of a day. Variations in response to day-night average sound level among communities can sometimes be explained by normalizing the data (see 7.4).

8.5.3 *Day-Evening-Night Average Sound Level* (Symbol L_{den}. An additional subscript may indicate the frequency weighting.)—This measure, very similar to day-night average sound level, is used primarily in California, where it is called Community Noise Equivalent Level (CNEL). In addition to the 10 dB night-time penalty, day-evening-night average sound