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

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1. Scope

1.1 This guide covers many measurement methods and criteria for evaluating environmental ~~noise. It~~ noise, some of which are required to be used for specific purposes by governmental regulations. It is intended to provide users who may not be familiar with them with an overview of the wide variety of available methods and criteria. It includes the following:

1.1.1 The use of weightings, penalties, and adjustment or 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 sources of selected available criteria; and

1.1.6 Suggested applications of sound level measurements and criteria.

1.2 *Criteria Selection*—Thorough evaluation of noise issues requires consideration of many characteristics of both the sound and the environment into which it is introduced. 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~~ community considering the magnitude and other characteristics of the sound and environment;

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

1.2.3 Identifying and evaluating compliance with regulatory requirements that do not specify an acoustical measurement method or criterion or which are unclear.

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

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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.~~Any investigation or evaluation of a community noise issue must start with identifying applicable regulations and evaluating compliance with them. This document discusses but is not limited to regulations and ordinances. Due to the wide variation in local regulations, those are discussed more generally, and specific criteria are provided only from national government regulations. Regulations typically specify measurement methods and criteria for purposes of the regulation. Local ordinances must be written for ease of enforcement and cannot address all situations satisfactorily without becoming too complex. Such ordinances are also often prepared without competent guidance and can be too restrictive in some cases and not restrictive enough in others. Other regulations that determine government spending for noise control must balance that cost to the general public against impacts on individuals.

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~~safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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 Statistical Sound Analysis System

2.2 *~~ANSI~~ASA/ANSI Standards:*[3]

~~ANSI~~ASA/ANSI S1.1 Acoustical Terminology
~~ANSI S1.4~~ASA/ANSI S1.4/Part 1/IEC 61672-1 ~~Part 1,~~ Electroacoustics – Sound Level Meters – Part 1: Specifications
ASA/ANSI S1.4-1983 Specifications for Sound Level Meters
~~ANSI S1.11~~ASA/ANSI S1.11/Part 1/IEC 61260-1 ~~Part 1,~~ Electroacoustics – Octave-Band and Fractional-Octave-Band Filters – Part 1: Specifications
~~ANSI~~ASA/ANSI S1.13 Measurement of Sound Pressure Levels in Air
ANSI S1.43 Specifications for Integrating-Averaging Sound Level Meters
~~ANSI~~ASA/ANSI S3.4 Procedure for the Computation of Loudness of ~~Noise~~Steady Sounds
~~ANSI~~ASA/ANSI S3.14 Rating Noise with Respect to Speech Interference
~~ANSI~~ASA/ANSI S12.4 Method for Assessment of High-Energy Impulsive Sounds with Respect to Residential Communities
~~ANSI~~ASA/ANSI S12.7 Methods for Measurement of Impulse Noise
~~ANSI~~ASA/ANSI S12.9 Quantities and Procedures for Description and Measurement of Environmental Sound – Part 1: Basic Quantities and Definitions; 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~~Use
ASA/ANSI S12.65 Rating Noise with Respect to Speech Interference
~~ANSI~~ASA/ANSI S12.100 Methods to Define and Measure the Residual Sound in Protected Natural and Quiet Residential Areas

2.3 *ISO Standards:*[3]

ISO ~~532~~532-1 ~~Acoustics—Method for Calculating Loudness Level~~Acoustics — Methods for calculating loudness — Part 1: Zwicker method
ISO ~~1996~~532-2 ~~Assessment of Noise with Respect to Community Response~~Acoustics — Methods for calculating loudness — Part 2: Moore-Glasberg method
ISO ~~2204~~1996-1:2016 ~~Guide to the Measurement of Airborne Acoustical Noise and Evaluation of Its Effects on Man~~Acoustics — Description, measurement and assessment of environmental noise — Part 1: Basic quantities and assessment procedures

[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, http://www.ansi.org.

2.4 *IEC Standard:Standards:*[4]

IEC 61260-1 Electroacoustics – Octave-band and fractional-octave-band filters – Part 1: Specifications

IEC Standard 6167261672-1: 2002 Electroacoustics-Sound Level MetersElectroacoustics – Sound level meters – Part 1: Specifications

IEC 61672-1: 2013 Electroacoustics – Sound level meters – Part 1: Specifications

2.5 *DIN Standard:*[5]

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

2.6 *United States Military Standard:*[6]

Mil StdMIL STD 1474E Department of Defense Design Criteria Standard Noise Limits

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.

3.1 *General*—This guide provides guidance for various measurement methods and criteria initially defined in other documents. Most acoustical terms used in this standard are defined in either Terminology C634 or within this standard with their abbreviations and symbols for use in equations. The definition of terms explicitly given within this standard take precedence over definitions given in Terminology C634. For interpretation of this document, the definitions within Terminology C634 and this standard take precedence over any other definitions of defined terms found in any other documents, including other documents that are referenced in this standard.

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)—level, CNEL, (dB), n—*see *day-evening-night average sound level*.

3.2.2 *day-evening-night average sound level (DENL), level, DENL, (dB),* L_{*den}—where * is a letter denoting the frequency weighting (understood to be A if deleted), *(dB), n—an* time average —a time-average sound level computed for a an average calendar day period with the addition of 4.77 dB or 5 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.

3.2.2.1 *Discussion—*

Various standards and regulations define both CNEL and DENL differently in terms of the level added to sound during the evening period. Earliest definitions indicated the average acoustic energy was to be multiplied by 3 which is equivalent to a 4.77 dB addition, but some more recent documents define the quantity with a 5 dB addition. In critical situations, the definition in a particular regulation or standard should be used.

3.2.3 *day-night average sound level (DNL),level, DNL,* $L*_{dn}$—where * is a letter denoting the frequency weighting (understood to be A if deleted), *(dB), n—an*—a time-average sound level computed for a an average calendar day period with the addition of 10 dB to all levelssound 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 sound sensation for which sounds may be ordereddescribed on a scale extending from soft to loud.loud or by a value in sones calculated from measured data. **ANSI S1.1**

3.2.4.1 *Discussion—*

– One sone is the perceived loudness of a 1000 Hz tone of 40 dB sound pressure level. A sound that is n times as loud is n sones.

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.

3.2.5.1 *Discussion—*

This term originated in methods developed in the 1950's and was adopted by the US Environmental Protection Agency. Some current standards use the word "adjustment" for the same concept.

3.2.6 *residual sound, n*—the all-encompassing sound, being usually a composite of sound from many sources from many

[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.

[6] Available from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, http://quicksearch.dla.mil.

directions, near and far, remaining at a given position in a given situation when all uniquely identifiable discrete sound sources of particular interest or considered an interference, whether steady or intermittent, are eliminated, rendered insignificant, or otherwise not included.

3.2.6.1 *Discussion—*

Residual sound is distinguished from background noise ~~which~~ (which by definition also includes the self-noise of measurement ~~systems,~~systems), and from ambient noise which includes all sound present. It is also distinguished from a steady sound that is dominant between discrete events. The specific sounds excluded from the residual sounds should be identified. If the excluded sound is ~~intermittent,~~ intermittent (such that it is on and off for periods), the residual sound may be approximated by the L90. If an excluded sound is steady and there are intermittent events, the L90 can be used to approximate the level of such steady sound and the residual sound must be measured with the steady source not operating or approximated by a measurement at a nearby location where the steady source is not dominant. Though "background noise" by definition includes instrument self-noise, the terms "background sound" and "background noise" are often used interchangeably with "residual sound" when it is known that instrument self-noise is not an issue.

3.2.7 *sound exposure ~~level,—~~level, *SEL, L_{*E}—* ~~*SEL~~ where * is a letter that denotes the frequency weighting (understood to be A if deleted), ~~*L(dB),*$_{*E}$ *where*~~*n* ~~* 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,~~—the sound energy 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.~~period or event expressed as the sound level of the equivalent energy over a period of 1 s.

3.2.7.1 *Discussion—*

The SEL can be computed as the time-average level of the sound over the event or stated period plus 10 times the base 10 logarithm of the event duration or stated period in seconds.

3.2.8 *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.

3.2.9 *steady sound, n*—sound with negligible variations in level over the period of observation.

3.2.10 *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, Part 1**~~

3.2.10.1 *Discussion—*

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, 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. **ASA/ANSI S12.9, Part 1**

3.2.11 *time weighting, n*—the exponential averaging of a time varying signal with a specified time constant.

3.2.11.1 *Discussion—*

Exponential time weightings are applied to sound signals to obtain measurements of a sound level at a specific time that has not been time-averaged. The two currently standardized time weightings are "slow" with a time constant of 1 s and "fast" with a time constant of ⅛ s.

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
community tolerance level	8.5.2
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 or adjustment of DNL	7.4
octave band, or one-third 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. Some evaluations are limited to determining compliance with existing regulations or ordinances. Others are done in the absence of such requirements or to supplement regulatory evaluations where the regulations do not address fully or at all the issues of concern.

4.2 *Selection of Criteria*—This guide ~~assists~~ provides information useful in selecting the appropriate criteria and measurement method to evaluate noise. In making the selection, the user should consider the following: regulatory or legal requirements for the use of a specific criterion; purpose of the evaluation ~~(compatibility,~~ (regulatory compliance, compatibility, activity interference, aesthetics, comfort, annoyance, health effects, hearing damage, etc.); ~~type~~types of data that are available or could be available (A-weighted, ~~octave-band,~~ octave band, average level, maximum level, day-night level, calibrated recordings including .wav files from which various measurements could be made, etc.); and available budget for instrumentation and manpower to obtain that ~~data; and regulatory or legal requirements for the use of a specific criterion.~~ data. After selecting a measurement method, the user should consult appropriate references for more detailed ~~guidance.~~guidance **(1)**.[7]

4.3 *Objective versus Subjective Evaluations*—This guide discusses objective sound criteria based on measurements and regulations based on such. Some local noise ordinances are based solely or partially on subjective judgements of noise. Enforcement of these can be easily challenged and, in some jurisdictions, they are not permitted. These are not further considered in this guide. One way to address such situations is to evaluate the sound based on reasonable objective criteria.

4.4 ~~*Objective versus Subjective Evaluations*—~~*Soundscape Methodology*—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~~ A soundscape evaluation methodology is evolving which includes 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~~perceived by people. ~~(~~Development~~1)~~ of such measurement methods specifically for soundscape studies is a part of ongoing research and is not specifically discussed in this document.

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~~ Historically the emphasis for noise evaluation in communities has been on annoyance, speech and sleep interference, and the effects of these on the usability of property. These effects occur at lower levels than typically required to damage hearing, influence task performance, or damage structures. Unless the scope of an evaluation is limited, it is important to recognize the many different problems that may be caused by ~~the noise. Sound-scape methods address~~noise. For example, Ref **~~aesthetic~~(2)** ~~components of sounds and provide for comfortable or satisfying sounds in addition to preventing noise problems.~~provides a comprehensive discussion of the effects of noise in the context of aviation 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~~

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

~~that~~ best-established criteria. Poor sleep or stress caused by annoyance can occur at much lower sound levels than required for hearing damage and can aggravate some ~~physical conditions. Criteria for preventing these problems are usually based on annoyance.~~ non-auditory physical conditions. Research has shown some physical reactions of the human body related to sound ~~including~~ exposure. These include 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. Communities with high noise levels also can have high levels of other pollutants that could cause physical problems. Thus, it is difficult to establish a direct connection between sound exposure and non-auditory health effects (~~2,~~ 3, 4~~)~~, 5, 6).

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

5.1.3 *Sleep Interference*—High levels of sound and changes in sound level can affect the quality of sleep or awaken sleepers. ~~See ANSI S12.9 Part 6.~~Annoying sounds can interfere with the ability to go to sleep. Poor sleep can affect physical ailments and contribute to the potential for degrading task performance that could result in injuries from accidents when driving or operating machinery (7).

~~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.~~

5.1.4 *Annoyance and Community Reaction*—Annoyance ~~and community reaction are different effects. Annoyance is~~ is the effect of a personal reaction to noise. Community reaction is the response to noise evidenced by complaints to ~~authorities.~~ authorities from multiple people. 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 community 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~~Some 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.

5.1.5 *Noise Characteristics*—Certain quantitative criteria can be used to further restrict sounds that have been found to be ~~particularity noticeable, intrusive~~particularly 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 such as octave band limits are used to specify or evaluate the aesthetic quality of the sound present. Some spectral criteria can be used to evaluate whether a sound is rumbly or ~~hissy,~~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. A major concern with music is often the bass beat because of its pulsating nature even if the level does not exceed normally acceptable criteria for steady low-frequency sound. In such cases, 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~~octave band limits in the low frequency bands set at a lower level than normal are sometimes applied specifically to the music. However, care must be used that such low limits are not inappropriately applied to steady ~~sounds when the problem is the time variation.~~ sounds. When sound levels vary strongly from an average, such as with aircraft overflights or an occasional heavy truck ~~passbys,~~ pass by, criteria that identify the variation such as "time above" or statistical counts of the number of events above specified thresholds or 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.~~and various recognized sound quality characteristics.

5.1.6 *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.~~As discussed in ASA/ANSI S12.9 Part 5, these criteria set maximum long-term average sound levels with appropriate adjustments for full and marginal compatibility of various usages with normal construction plus in some cases a higher level in which the use is compatible with improved construction. The criteria for residential uses assume the community is populated by people of average sensitivity to annoyance regardless of sound level with no self-selection based on existing levels. The ranges are wide enough that noticeable and potentially significant changes in sound level could occur within a given compatibility category without exceeding the criteria. For these reasons as explained in the standard, these criteria do not predict community reaction to sudden significant increases in the average sound level.

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

5.1.7 *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. Refs (**8, 9**) discuss criteria for national parks and wilderness areas, Ref (**10**) discusses rural areas, and ASA/ANSI S12.100 discusses measurements of residual sound in such areas.

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 and IEC Standard 61672. Meters may include filters to measure sound in specific frequency bands. Specifications for theseA classification of the types of sounds by temporal, frequency, and spatial characteristics, as well as basic procedures for taking sound pressure level measurements at a single point in space based on these different characteristics, are found in ANSI S1.11. A classification of the types ofASA/ANSI S1.13. Various measurements discussed in Section 8 sounds, as well as basic procedures for taking sound pressure level measurements at a single point in space, are found in ANSI S1.13.below are affected by capabilities built into the sound level meters used for measurements. This section discusses these capabilities and standards for instruments.

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. They adjust the relative strength of sounds occurring at different frequencies before the level is indicated by the meter. 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. used. Results are expected to indicate human perception or the effects of sound on humans. humans, most closely correlating (though not exactly) with perceived loudness. A-weighting accounts for the reduced sensitivity of humans to low-frequency sounds, especially at lower sound levels. In addition to A-weighted sound levels, the weighting curve can be applied to spectra to evaluate the contribution of various frequencies to the A-weighted sound level.

6.2.2 C-weighting is sometimes used to evaluate sounds containing strong low-frequency components. A large difference between C and A weighted levels identifies the presence of strong low-frequency sound. 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. have been defined but are not in current instrument standards. The Z-weighting defines the frequency limits of the previously non-standardized "unweighted," "linear," or "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. These are sometimes referred to as a "response" such as "slow response."

6.3.1 "Slow" is the most a commonly used time weighting. It weighting especially in local ordinances because it provides a slowly changing level indication that is easy to read and is often specified in regulations.read.

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. The impulse time weighting is no longer required in sound level meters. As stated in Annex C of IEC 6167261672-1:2002, various investigations have concluded that it "is not suitable for rating impulsive sounds with respect to their loudness – nor for determining the 'impulsiveness' of a sound." Since impulse response has been used in some ~~regulations,~~ regulations such as for gunshot sound, the historical specifications for this time weighting ~~are~~were included in Annex C of IEC ~~61672.~~61672-1:2002 but are not included in the 2013 version.

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.~~different maximum and minimum levels for typical varying sound levels but yield the same level for a steady source.

6.4 *Peak Sound Pressure Level*—A peak indicator measures the true peak level of a very short duration signal. It is not normally used to measure steady sounds or slowly varying sounds. A peak detector responds to the absolute positive or negative instantaneous value of the waveform rather than its effective or "root mean square" (rms) value. 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. The measured peak level is dependent on the frequency bandwidth of the microphone and both the frequency bandwidth and the rise time (microseconds/volt) of the associated electronic instrumentation. A reduced frequency bandwidth will reduce the effective rise time. Sound level meter standards specify tolerances for accuracy of the C-weighted peak level but not the rise time. When Z-weighting is used, it is important to validate the performance of ~~your instrumentation using for example~~the instrumentation using, for example, a method given in ~~Mil Std~~MIL STD 1474E section 4.7.4.3. ~~C-weighting can reduce the influence of wind on the microphone and low frequency instrument self-noise on the measured result. The difference between results measured with Z or C weighting is often minor.~~ Some criteria for gunshot sound are based on Z-weighted peak levels. Measuring such at points far from the source can be difficult because even low-speed wind blowing over a microphone can produce a signal below the frequency range of the gunshot that exceeds the level of the gunshot. C-weighting can function like a high-pass filter eliminating the wind effect and allowing the gunshot sound to be measured with little or no wind effect. Rise time can be an important factor in some cases such as measurements close to a firearm. ~~(In~~In order to minimize confusion, the term "peak" should never be used to describe the maximum level measured with fast or slow time ~~weighting.)~~weighting since true peak levels can be more than 20 dB greater than maximum time-weighted levels.

6.5 *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.) 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~~ (IEC 61260-1, ASA/ANSI S1.11/Part 1/IEC 61260-1). Octave band or one-third octave band data or criteria are understood to be Z weighted unless it is clearly stated otherwise. Frequency analysis can 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.

6.8 *Sound Level Meters and Filters*—Early sound level meters included the fast and slow time weightings and A and C frequency weightings and no ability to average over longer periods. Most newer instruments include the ability to make time- average sound level measurements. The sound level meter specification standard does not call for frequency analysis filters. However, such can be built into meters or attached. Other features such as percentile analysis, and long-term monitoring with measurements over selected periods are often found in modern instruments.

6.8.1 Sound level meters for field use are designated as either class 1 or class 2, with class 1 being more precise.

6.8.2 International specifications for sound level meters are provided in IEC 61672-1. This standard is often adopted by nations as a national standard, and this was done in the United States in 2014 as ASA/ANSI S1.4/Part 1/IEC 61672-1. This standard defines both a "time weighting" meter also called a "conventional" meter in ASA/ANSI S1.13 and the modern "integrating-averaging" meter with selectable averaging time. Prior to 2014, standards for sound level meters in the United States were specified in ASA/ANSI S1.4-1983 for conventional sound level meters and ANSI S1.43 for integrating-averaging sound level meters. These standards contained more stringent tolerances at low frequencies than the current standard or earlier IEC standards.

6.8.3 International specifications for octave band and fractional octave band filters are provided in IEC 61260-1. This standard is often adopted as a national standard. In the United States this is ASA/ANSI S1.11/Part 1/IEC 61260-1.

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 Penalties*—Many people expect and need lower sound levels at night, primarily for sleep and relaxation. In most outdoor locations, ambient noise 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.~~pm until 7:00 ~~a.m.~~am. 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.~~ level (see 8.5.2). In some cases an evening penalty of approximately 5 dB is also ~~used.~~used (see 8.5.3).

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.~~ are concentrated at a specific frequency, or a series of frequencies that are typically multiples of the lowest such frequency, are called tonal with the individual frequencies being discrete tones. Such sounds give the sensation of pitch. 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.~~sounds. In such cases, ~~it is common for~~ local noise ordinances ~~to~~sometimes specify that the objective criterion be 5 dB more stringent than would be the case if the sound character were ~~broad-band and steady.~~not tonal or impulsive.

7.4 *Normalization or Adjustments to Sound Levels*—Some criteria presume conditions that are not appropriate in all cases. When these conditions are not met, the measured level ~~is~~ can be adjusted or normalized for the different conditions before comparing it to the normal criterion. This is done by adding or subtracting a number of decibels from the measured or calculated expected level for each factor different from the normal assumption. ~~Table 1 shows typical adjustments suggested by the~~ The U.S. Environmental Protection Agency (EPA) (**~~5~~11**) ~~in its "normalization" procedure. Similarly, ANSI~~provided a "normalization" procedure when it introduced the DNL because it found that such adjustments provided much better correlation with community reactions. Most of the EPA adjustments were taken from earlier procedures but with some changes. The EPA adjustments addressed seasonal differences, existing sound in the community without the noise, prior community experience with the noise or community attitudes, and tonal or impulsive characteristics. Similarly, ASA/ANSI S12.9 Part 4 provides ways to account for various residual or background sound conditions and sound characteristics. The measured or calculated DNL is "adjusted" upward by 5 dB for tonal or normal impulsive sound or sound occurring during daytime on weekends, 12 dB for highly impulsive sound such as small arms gunfire, hammering, riveting, and railyard shunting operations, up to 5 dB for normal aircraft sound, and up to 11 dB for rapid onset ~~sound~~ such as from fast, ~~low-flying aircraft.~~ lowflying aircraft. More complex adjustments are made for strong low-frequency content and high-energy impulsive sounds. The result is called the "adjusted DNL." In an Annex, this standard suggests that in evaluating expected annoyance, appropriate adjustments are up to 5 dB for new sounds and up to 10 dB in quiet rural areas, with the two adjustments being additive. Of all these normalization or adjustment factors, only the rapid onset adjustment has been incorporated in US federal regulations. The discrete tone or impulsive adjustment is sometimes found in local noise ordinances.

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~~are used in the methodology called "sound quality" to evaluate and improve the sound of products. Only loudness (see 8.11~~S3.4 and ISO 532) and sharpness (DIN 45692)~~) 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.~~standards (**~~6~~12**~~)~~).

8. Sound Measurements, Their Best Uses and Weaknesses

8.1 *Introduction*—There are many ways of measuring and specifying limits on sound. ~~The~~ Sometimes a measurement method and criterion are specified in a regulation that must be used to determine regulatory compliance. If an evaluation is for other purposes, the most appropriate measurement method and criteria should be selected for ~~a specific case.~~ the specific situation. Sometimes multiple methods could be needed. 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~~ criterion based on change in level, possibly also considering changes in other characteristics, 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.~~9. Further guidance on the use of the most common measures of overall sound in the outdoor environment, as discussed in ~~8.2–~~8.2–8.7,~~8.7,~~ can be found in the ~~ANSI~~ASA/ANSI S12.9 series of standards.

8.2 *Level of Steady Sound*—When sound is steady, and its frequency content is stable the sound level can be measured with simple instrumentation without the need for averaging or statistical ~~sampling.~~ sampling unless required by a regulation. Criteria may simply state that the sound must 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~~ or a possibility that the sound may not ~~be steady in environments where it should be.~~actually be steady, more complex criteria and measurements are necessary.

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 (commonly used in local ordinances) 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. 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~~ This type of criterion with appropriate limits higher than those for continuous sound 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 at an appropriate higher level for such brief sounds are often used in combination with other ~~criteria.~~ criteria at a lower level for continuous sound. Maximum sound level limits alone are insufficient for specifying community noise ~~criteria. If set appropriately for short duration noise, maximum sound~~ criteria as they cannot appropriately control both brief sounds and continuous sounds. Sometimes only maximum 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.~~stated at levels more appropriate for an average level and inappropriate for occasional brief duration sounds. This results from criteria originally based on the maximum for a "sound level" that was an eyeball average reading of a fluctuating meter needle. In modern usage, "maximum level" instead refers to the highest sound level observed over a period, which could be significantly higher than the average over the period.

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.~~ASA/ANSI S12.7. Peak levels involve no averaging and are much higher than the maximum levels measured with fast or slow time weighting so that appropriate peak criteria must be applied.

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~~ non steady sounds especially when they vary over only a few ~~decibels. It also can be used where the variation in level is large. High-level short-duration events strongly influence the time-average level. There~~ dB. High-level short-duration events strongly influence the time-average level so it imposes some limit on such. However, there is some psychoacoustics uncertainty whether two sounds of the same energy equivalent level are always perceived by people to be equally loud or annoying. ~~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. Also, in that circumstance the steady sound might not be a problem indoors while the loud events would be clearly heard indoors. 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 lower limits at night with short-duration time-average levels, or night-time or evening penalties to compute modified long-duration time-average sound levels. The most familiar of these ~~descriptors~~ long-duration metrics is the day-night average sound ~~level.~~ level (DNL). 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~~ASA/ANSI S12.9 Part I.