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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 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

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

ANSI S12.40 American National Standard Sound Level Descriptors for Determination of Compatible Land Use

2.3 *ISO Standards:*[3]

ISO 532 Acoustics—Method for Calculating Loudness Level

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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.

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. Certain basic terms are defined in Terminology C 634.

3.2 *Definitions*—The following commonly used terms are discussed in the sections referenced in this guide and defined in the referenced standard or other document.

3.2.1 *A-weighting*—Paragraph 6.2; ANSI S1.4.

3.2.2 *C-weighting*—Paragraph 6.2; ANSI S1.4.

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

3.2.4 *day-evening-night average sound level,* L_{den}—Paragraph 8.5.3; ANSI S12.9.

3.2.5 *day-night average sound level (DNL),* L_{dn}—Paragraph 8.5.2; ANSI S12.9 and ANSI S12.40.

3.2.6 *equivalent level (LEQ),* L_{eq}—see *time-average sound level*.

3.2.7 *fast, time weighting or sound level*—Paragraph 6.3; ANSI S1.4.

3.2.8 *impulse, time weighting or sound level*—Paragraph 6.3; ANSI S1.4.

3.2.9 *loudness*—Paragraph 8.12; ANSI S3.4; ISO 532.

3.2.10 *noise pollution level (NPL),* L_{NP}—Paragraph 8.7; Ref **(1)**.[5]

3.2.11 *normalization*—Paragraph 7.4; Ref **(2)**.

3.2.12 *octave band, or 1/3 octave band*—Paragraphs 6.6 and 8.10; ANSI S1.11.

3.2.13 *peak sound level*—Paragraphs 6.4 and 8.4; ANSI S1.4.

3.2.14 *percentile level*—Paragraph 8.6; ANSI S12.9.

3.2.15 *slow, time weighting or sound level*—Paragraph 6.3; ANSI S1.4.

3.2.16 *sound exposure level (SEL),* L_E—Paragraph 8.5.4; ANSI S12.9 and ANSI S12.40.

3.2.17 *speech interference level (SIL)*—Paragraph 8.11; ANSI S3.14.

3.2.18 *time above*—Paragraph 8.8; ANSI S12.9.

3.2.19 *time-average sound level*—Paragraphs 6.5 and 8.5.1; ANSI S12.9 and ANSI S12.40.

3.2.20 *time-weighted average sound level (TWA)*—Paragraph 8.9; Ref **(3)**.

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 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

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

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

particularly perceptible and intrusive. 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 tone. Sounds that do not meet aesthetic quality criteria are sometimes restricted to lower overall 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.

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 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 concentrated within a narrow frequency band are called discrete tones. These can be particularly perceptible, intrusive, unpleasant, and annoying. The same is true of sounds consisting of repeated pulses less than a second apart. 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 Level of Time Varying Sound* (Symbol L_{max}. Additional subscripts may be used to denote frequency and time weighting.)—Some criteria state maximum 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, but any sound below that level is fully acceptable. Maximum level limits are often used in combination with other criteria. Maximum level limits alone are insufficient for specifying community noise criteria. If set appropriately for short duration noise, maximum level limits are too high to limit continuous noises properly.

8.4 *Peak 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 gunshots or hammer blows, it is appropriate to use the peak level.

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

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
Pure tone or impulse	No pure tone or impulsive character	0
	Pure tone or impulsive character present	+5

use of energy equivalent measures is uncertainty about whether two sounds with the same energy equivalence are perceived to be equally loud. 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.

8.5.1 *Time-Average Sound Level* (Symbol L_T, where T 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 level adds a penalty of approximately 5 dB to all sound between 7:00 p.m. and 10:00 p.m. before computing the average.

8.5.4 *Sound Exposure Level* (Abbreviation SEL and Symbol L_E. An additional subscript may indicate the frequency weighting.)—It is often useful to compare the total sound energy among discrete events or the total energy accumulated over periods of different durations. This can be accomplished by converting the time-average sound level of the event or period to an energy-equivalent level for a sound lasting exactly 1 s. This is the sound exposure level. For sounds lasting more than 1 s, the sound exposure level will always be greater than both the average and maximum levels of the sound. The way in which the event duration is defined may be either a specific time, the time during which the sound is within 10 dB of the maximum level, the time the sound is above a specified level, or the time the sound is above the average background sound level. The most common use of sound exposure level is in databases for aircraft noise, from which day-night average sound level may be computed. The disadvantages of sound exposure level in criteria are that people do not easily understand it, and there is little research relating sound exposure level to effects.

8.6 *Percentile Level* (Abbreviation LX and Symbol L_x, where X = a number from 1 to 99 indicating the percentage of time the level is exceeded. Additional subscripts may indicate the frequency and time weighting.)—This is an indication of the sound level that is exceeded for a stated percentage of a measurement period. It is also commonly called percentile exceedance level. For instance, the level exceeded 90 % of the time for a stated period is the 90 percentile level or L90. This is often taken as an indication of residual or background sound present from unidentifiable sources. The 10 percentile level, L10, and the median level, L50, are sometimes used to state community noise limits. The median level alone as a criterion has a particular weakness. Very loud levels could occur almost 50 % of the time and not be reflected in an evaluation. The 10 percentile level is more likely to reflect the presence of loud sounds unless they occur during less than 10 % of the measurement or analysis period. Using the 10 percentile level to specify limits rather than time-average sound level will often impose a lower effective limit on sound with varying sound levels compared to a steady sound. Some criteria place limits on the amount by which the maximum level of a new sound can exceed the previously existing 90 percentile level. However, the use of such a criterion alone can allow unacceptable increases in sound if the new sound is present during a high percentage of the time. Guide E 1014 and Test Method E 1503 provide methods of gathering data for determination of percentile levels.

8.7 *Noise Pollution Level* (Abbreviation NPL and Symbol L_{NP})—Both time-average sound level and percentile levels have weaknesses in describing the perception of sound. Time-average sound level does not assess the variation in sound level, and no single percentile level can fully measure the noise. Some descriptors have combined the two by adding a fluctuation factor to the time-average sound level. One such descriptor is the noise pollution level $L_{NP} = L_{eq} + 2.56\sigma$, where σ is the standard deviation of the instantaneous sound levels. Another form of this is $L_{NP} = L_{eq} + (L_{10} - L_{90})$, where the addition and subtraction are arithmetic.

8.8 *Time-Above*—This is the time above a stated sound level during a stated measurement period. In some situations sound below a given threshold may not present a severe problem. However, the degree of the problem is related to the time above the threshold more so than the actual maximum level. For instance, aircraft noise may interfere with activity in an office only during the time it exceeds some level. The amount of time above this level could be the key information of concern. Care should be used with this criterion, since it sets no limits on the sound below the threshold or on the degree to which the threshold is exceeded.

8.9 *Time-weighted Average Sound Level* (Abbreviation and Symbol TWA)—Criteria for evaluating the potential for hearing damage from high noise levels in the workplace are expressed by a special time-weighted average sound level. The TWA expresses the total sound exposure in a workday as an equivalent 8 h steady level. However, the TWA is not always based on an energy-equivalent or 3dB exchange rate. Pertinent regulations specify an exchange rate indicating the number of decibels considered to double hearing damage risk. TWA is often computed from sampled measurements of the A-slow-weighted sound level. Sometimes a threshold level is specified, and sound levels below this threshold are not included in the computation of the TWA. See Refs **(3)** and **(4)** and "noise exposure level" in ISO 1999.

8.10 *Octave-Band (or 1/3 Octave-Band) Criteria*—Often a single overall sound level is not sufficient to evaluate or specify the noise environment fully. This is especially the case for steady sounds of long duration. In such cases it is usually desirable to ensure that the quality of the sound matches the normal expectation in the environment. Evaluating both aesthetic appeal and speech interference requires knowledge of the frequency content of the sound. The most common criteria of this type are the octave-band curves used to evaluate and rate the steady background sound in rooms. Similar curves have been used for evaluating outdoor community noise. In the outdoor environment it is usually assumed that the noise controlled or evaluated by such criteria is steady. Better availability of instruments for rapidly measuring octave-band levels of non-steady sounds may lead to wider use of these criteria for such sounds. Criteria based on 1/3 octaves are rare.

8.11 *Speech Interference Level* (Abbreviation SIL)—The speech interference level is based on octave-band sound pressure levels. However, it is a single number. It is the arithmetic average of the steady sound pressure levels in the three or four octaves that most affect the understanding of speech. It is often used for a first approximation to find the distance at which speech of a given voice level can be understood in the environment. For this use, it is clearly superior to A-weighting.

8.12 *Criteria Based on Loudness*—Differences in perceived loudness are not always indicated correctly by the A-weighted sound level. More accurate methods have been devised to quantify human perceptions of loudness. These require calculations using sound pressure levels measured with a frequency analyzer, usually in octave or one-third octave bands. Recent electronic technology advances make it possible to program the calculation procedures within measurement instruments, making these criteria more practical for use in the field. Current standard methods apply only to steady sounds. However, research indicates potential for a better method of quantifying the perceived loudness of a sequence of events during a period.

9. Considerations in Criteria Selection

9.1 The selection of criteria and measurement methods for a particular project is influenced by the goals of the evaluation, regulatory requirements, budget constraints, and the availability of existing data.

9.1.1 *Regulatory Requirements*—These include workplace noise exposure limits, local community noise regulations, construction regulations to limit indoor levels due to outdoor noises in noisy areas, and requirements to qualify for financing of construction. These regulatory requirements are often minimum requirements.

9.2 *Goals of Evaluation*—Regulatory criteria may be insufficient to guide the design of high-quality environments or to determine the effects of new sounds on such environments. More complex measurements and criteria may be needed.

9.3 *Budget and Availability of Data*—The cost of measurements for various criteria can vary significantly. In some cases some data may be readily available. It is usually best to evaluate the sound based on the simplest criterion first, as this can give some indication of the need to proceed with further analysis.

10. Applications of Sound Level Measurements and Criteria

10.1 *Introduction*—Criteria for sound levels and sound exposure play an important role in evaluating and regulating noise in the environment. Some local, state, and provincial governments have extensive regulations to assist in the planning and control of noise in the environment. In other places there are no formal planning efforts or regulations referencing noise levels. Situations then have to be evaluated and problems resolved without the assistance of relevant regulations. Land use planning based on noise exposure is essential near major transportation-noise sources. Local regulations on noise crossing boundaries can be useful in any community. However, these become more essential as the density of population in a community increases. This section discusses the following frequent specific uses of sound level measurements and criteria.

10.1.1 Environmental impact assessment.

10.1.2 Formal land-use-planning activities.

10.1.3 Evaluating the suitability of a site for a particular use.

10.1.4 Local government regulation of noise crossing boundaries through general or zoning ordinances.

10.1.5 Resolving noise disputes in the absence of relevant regulations.

10.1.6 Inspection of buildings for satisfactory interior sound levels.

10.2 *Environmental Impact Assessment*—Formal environmental impact statements are often required for specific projects expected to increase noise in a community. Examples include new, expanded, or upgraded airports, highways, utility plants, and quarry operations. The environmental impact statement will usually show existing and projected future noise. This is often accomplished graphically with a set of sound level contour maps. For airports, the day-night average sound level is preferred and used almost universally. In some cases this is supplemented by a measure of single event noise. Highway assessments are usually based on the 10 percentile level or time-average sound level for the worst hour of the day.

10.3 *Land Use Planning*—Many communities have found it helpful to establish land-use-planning programs based partially on varying noise levels in the community. These programs usually use long-term average-level contours based on day-night average sound level. The contours most commonly reflect noise from major transportation noise sources such as airports, highways, or railroads. The contours usually establish lines of equal day-night average sound level in 5 dB increments on a map. Land within the contours is zoned for uses compatible with the expected noise exposure. Highway and aircraft noises with the same day-night average sound level often are considered equivalent. This may not be valid for some land uses. For instance, a highway producing a day-night average sound level of 75 dB may be almost unnoticeable in an office building. However, aircraft noise with the same day-night average sound level could produce many disrupting events with maximum A-weighted sound levels of more than 70 dB in the same building. The better planning efforts also relate housing types to noise exposures. Higher-density, multi-family apartments with few outdoor amenities are more compatible with high noise levels than single-family homes on large lots with outdoor pools. Planning guidelines are best used to guide new development where options are available to make the development compatible with the noise.

10.4 *Site Suitability*—Property owners or buyers often have to determine whether a site is suitable for a particular use. The use may demand peace and quiet, or it may produce a lot of noise that would be difficult to control in a very quiet area. If the community has extensive noise planning activities, there may be data available from the planning office to help in the evaluation. Such data are often in the form of day-night average sound level contours. These types of average-level data may not be sufficient if the proposed site use requires existing steady noise levels to mask its sound, or if high maximum noise levels would affect the use. The evaluator may have to develop a measurement and evaluation program consistent with the needs of the particular planned use. Various measurement techniques and criteria might be used depending on the specific situation.

10.5 *Local Ordinances*—Many state, provincial, and local governments have adopted quantitative ordinances and bylaws limiting sound crossing real property boundaries. These may be in the form of either general or zoning ordinances. The limit imposed is usually determined by the use of the property onto which the sound is traveling. Thus, an industrial plant next to a residential property is subjected to a lower limit than one surrounded by other industrial properties. Sometimes both the source and receiver property uses are considered in setting the limit. Setting the limit based solely on the source property results in unreasonably high noise transmitted from industrial to residential usages.

10.5.1 Practical criteria for local ordinances are based on a measurement that can be performed in less than 1 h. Most good ordinances use either a percentile level or a time-average sound level over some period of 1 h or less, combined with a maximum-level criterion. Some supplement this with octave-band criteria. The time-average sound level or statistical measure should be over a period of at least 10 min, and preferably longer, to be reasonable. Maximum level criteria should not be used alone in ordinances. A reasonable maximum-level limit for a continuous sound would be too low for a very brief noise occurring infrequently. Such a reasonable limit for the infrequent brief noise would be too high for the continuous noise. Time-average sound level is becoming popular as new instruments make it easy to measure. Earlier ordinances frequently used the 10 percentile level as a criterion and measured it manually with a sampling technique of 100 measurements 10 s apart.

10.5.2 Some ordinances set the limits in part based on the residual or expected ambient noise in the community. Sometimes this is done using the noise expected from the road traffic as the basis. Any ordinance should have a provision to ensure that the noise being cited as excessive is truly greater than the normal community ambient. However, most ordinances do not consider variations in the expected ambient within the adopting community. Thus, a noise that is creating a problem in a very quiet part of the community may not exceed the ordinance limit. Such ordinances that do not consider normal local ambients prevent only the worst problems. They do provide an easy way for someone facing such a major problem to seek relief. It need only be shown that the noise exceeds the limit in the ordinance. However, they do not ensure that everyone will be pleased. Those finding a noise that meets the ordinance to still be objectionable bear the burden of proof in court.

10.6 *Problem Resolution*—Acoustical consultants and local officials are often called upon to resolve disputes between land-owners when one introduces a noise impacting a neighbor. A quantitative local ordinance limiting the sound crossing property boundaries can be useful if such exists. Many locations have no such ordinances. Even when ordinances exist, there may be problems not resolved by the ordinance. This occurs when the noise crossing the boundary does not exceed the limit of the ordinance but still creates a problem. Resolution of the situation requires a careful selection of appropriate criteria and evaluation according to those criteria.

10.7 *Building Inspection*—In some noisy areas, regulations require that the building structure be sufficient to limit the indoor sound level that is due to outdoor sources. These regulations will specify a criterion for the indoor sound level. They will usually use levels from land-use-planning documents to define the outdoor level. To determine compliance, it may be necessary to measure the outdoor and indoor sound levels simultaneously. The outdoor-indoor level reduction is then established according to Guide E 966. This level reduction should then be applied to the expected long-term outdoor noise to determine whether the structure is in compliance. It is not reasonable to measure only the indoor noise levels since the outdoor levels during the measurement may not be those normally present in the community.

11. Sources of Criteria and Representative Available Criteria

11.1 *Standards*—There is only limited information on environmental noise criteria available in national standards. The American National Standards Institute (ANSI) and the International Standards Organization (ISO) each have standards on environmental noise criteria for certain circumstances. Other ANSI and ISO standards on measurement methods provide criteria information for reference. The following is a partial list of standards (from Section 2) that could be useful in particular situations: ANSI S3.1, ANSI S3.4, ANSI S3.14, ANSI S12.4, ANSI S12.7, ANSI S12.9, ANSI S12.40, ISO 532, ISO 1996, ISO 1999, and ISO 2204. ANSI S12.40 describes use of day-night average sound level and provides reference information on land uses compatible with various day-night average sound level values.

11.2 *National Government Guidelines and Regulations*—The U.S. government has established guidelines for noise exposure based on day-night average sound level. Initially, a day-night average sound level of 55 dB was established as the level required to protect the public health and welfare with an adequate margin of safety. The current guidelines for land use compatibility used by most U.S. agencies consider cost and technical feasibility in addition to impact of noise on people. Most of these guidelines indicate a day-night average sound level of 65 dB or lower to be compatible with residential use. This recognizes that many people will accept noise to this level provided there are other primary reasons to live at that location. This criterion can be misleading if used to evaluate the impact of a new or increased noise on a community where acoustical quality is a primary asset. When the EPA first introduced the day-night average sound level, it recommended that the day-night average sound level in a community should be normalized for local conditions to better correlate with the community reaction **(2)**. No U.S. federal agency currently normalizes day-night average sound level data for local conditions or looks at other important criteria such as maximum sound levels or day-night average sound levels for periods of less than one year. The Committee on Hearing, Bioacoustics, and Biomechanics of the U.S. National Research Council provides guidelines for developing environmental impact statements on noise. Criteria for noise exposure in working environments for the protection of hearing are in the U.S. Occupational Safety and Health Regulations. The Canadian government has published comprehensive national guidelines for environmental noise control including recommended criteria. Refs **(2 and 3)** and **(5-11)** are selected national government publications.

11.3 *State, Provincial, and Local Government Guidelines and Regulations*—Guidelines and Regulations too numerous to list in this guide have been adopted by various state, provincial, and local governments. At least eleven states, as well as Puerto Rico and the District of Columbia, have regulations controlling noise in various land uses. As of 1975, a study published by the EPA **(9)** indicated that at least 118 cities or local governments in the United States imposed limits on noise crossing onto residential properties. Slightly fewer also imposed limits for noise crossing onto commercial and industrial properties. This study tabulated and averaged the limits but unfortunately did not differentiate among types of measurement such as maximum level, time-average sound level, or 10 percentile level. Most local ordinances are based on measurements of the A-weighted sound level over a period of less than 1 h. The most widely used daytime limit for residential areas was 55 dB, followed by 60 and 50 dB. At night, the most widely used limit in residential areas was 50 dB, followed by 45 and 55 dB. In commercial areas, the most popular limits were 60 and 65 dB during the daytime and 55 and 60 dB at night. In industrial areas, the most popular limits were 70 and 75 dB, without distinction between day and night. Where such local laws do not exist, review of several local ordinances from other jurisdictions could be helpful in establishing criteria.

11.4 *Technical Society Publications, Books, and Research Papers*—The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) publishes guidelines for steady noise in various types of indoor spaces. These guidelines have been widely used and accepted as appropriate. While it is normally expected that the primary source of steady indoor noise would be ventilation equipment, there could be other sources, including outdoor noises penetrating the building. Several books with good summaries of various criteria for noise are widely used by professionals in acoustical evaluation. Criteria for some situations have been examined and developed by researchers but not yet included in standards or regulations. In some cases the only way to find appropriate criteria could be in published technical papers. Ref **(1)** and **(12-17)** can guide the selection of criteria.

12. Keywords

12.1 community noise; environmental noise; noise; noise assessment; noise criteria; noise evaluation; noise level measurement; noise metrics

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