ANSI S1.13-2005
(Revision of ANSI S1.13-1995)

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AMERICAN NATIONAL STANDARD

Measurement of Sound Pressure Levels in Air

ANSI S1.13-2005

Accredited Standards Committee S1, Acoustics

Standards Secretariat
Acoustical Society of America
35 Pinelawn Road, Suite 114 E
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Measurement of Sound Pressure Levels In Air

Secretariat:
Acoustical Society of America

Approved by American National Standards Institute, Inc.
25 July 2005

Abstract

This standard specifies requirements and describes procedures for the measurement of sound pressure levels in air at a single point in space. These requirements and procedures apply primarily to measurements performed indoors but may be utilized in outdoor measurements under specified conditions. This is a fundamental standard applicable to a wide range of measurements and to sounds that may differ widely in temporal and spectral characteristics; more specific American National Standards complement its requirements. A classification is given of the types of sound generally encountered, and the preferred descriptor for each type is identified. This standard is intended to be used by practitioners in the field, as well as by members of the general public who have little or no special technical training in areas relating to acoustics. This is a replacement for a previous version of ANSI S1.13.

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Foreword

[*This Foreword is for information only, and is not a part of the American National Standard ANSI S1.13 – 2005 American National Standard Measurement of Sound Pressure Levels in Air*].

This standard comprises a part of a group of definitions, standards, and specifications for use in acoustics. It was developed and approved by Accredited Standards Committee S1 Acoustics, under its approved operating procedures. Those procedures have been accredited by the American National Standards Institute (ANSI). The Scope of Accredited Standards Committee S1 is as follows:

> *Standards, specifications, methods of measurement and test, and terminology in the field of physical acoustics, including architectural acoustics, electroacoustics, sonics and ultrasonics, and underwater sound, but excluding those aspects which pertain to biological safety, tolerances, and comfort.*

This standard is a limited revision of ANSI S1.13-1995, which has been technically revised by updating the references in the body and replacing Annex A in its entirety.

This standard is not comparable to any existing ISO Standard.

At the time this Standard was submitted to Accredited Standards Committee S1, Acoustics for approval, the membership was as follows:

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Working Group S1/WG 4, Measurement of Sound Pressure Levels in Air, which assisted Accredited Standards Committee S1, Acoustics, in the development of this standard, had the following membership.

M.A. Nobile, Chair

E. Dunens R.D. Hellweg

Suggestions for improvements of this standard will be welcomed. They should be sent to Accredited Standards Committee S1, Acoustics, in care of the Standards Secretariat of the Acoustical Society of America, 35 Pinelawn Road, Suite 114E, Melville, New York 11747-3177. Telephone: 631-390-0215; FAX: 631-390-0217; E-mail: asastds@aip.org

Introduction

Sound is a pressure fluctuation in the air. In general, the greater the amplitude of the pressure fluctuation, the "louder" the sound will be perceived by people. But loudness is a *subjective* measure of the amplitude that varies from one person to the next and will depend on many parameters, some of which are nonphysical. The need often arises for an *objective* measure of the amplitude of the pressure fluctuations, a measure that depends solely on physical parameters and that is not subject to interpretation or opinion. Sound pressure level is this objective measure. This standard gives requirements and guidelines for measuring the sound pressure level in air at a single point in space.

The total ambient sound that exists at a given point in space is usually due to a composite of many different sounds with different strengths and frequency content. The composite sound may be a combination of background noise and sound from a single identifiable source; it may be a combination from several individual sources; and it may include reflections from room surfaces or reflecting objects. This standard is primarily concerned with the measurement of the level of the composite sound at a given point or in measuring changes in that level caused by a certain sound of interest.

This standard (ANSI S1.13-2005, Measurement of Sound Pressure Levels in Air) is a fundamental standard giving basic information and requirements for a wide range of measurements. Other American National Standards provide more specialized information and requirements.

The way in which the sound pressure level varies with time (temporal pattern), how it varies over frequency (frequency content), and how it varies from one physical point to another (spatial distribution) are often important. The desire to quantify these aspects has led, unfortunately, to a preponderance of metrics and descriptors in use today, some quite complicated and some limited to very specific applications. Fortunately, the advent of modern digital instruments of relatively low cost and wide availability and the efforts by standardization bodies have led to a general consensus on only a small number of descriptors. This standard identifies the time-average A-weighted sound level and the A-weighted sound exposure level as preferred descriptors for the various types of sounds defined in the text.

There are many reasons for measuring sound pressure levels. These include regulatory purposes, quantifying noise emissions of products, assessing hearing-damage risk, designing acoustical spaces, monitoring the condition of a machine, evaluating the performance of sound sources such as loudspeakers or emergency sirens, evaluating hearing protectors, absorptive materials, or barriers, and assessing various subjective responses such as loudness, noisiness, speech-interference level, and articulation index. However, most purposes for sound pressure level measurements fall into two groups: sound pressure levels measured in order to characterize a source, and sound pressure levels measured in order to characterize an environment. Regardless of the reasons, or whether one is trying to characterize a source or an environment, the process will involve individual measurements of the sound pressure level at one or more specific points in space. This is the focus of this standard. The particular reasons or applications for the measurements are dealt with only superficially.

This standard is intended to be used by practitioners in the field as well as by members of the general public who have little or no special technical training in areas relating to acoustics. One of the goals of publishing this standard is to make the practice of making an accurate sound pressure level measurement more widespread and comfortable.

It is anticipated that standards, test codes, government regulations, purchase specifications, design specifications, or similar documents requiring the measurement of sound pressure levels will refer to this standard in a form such as "... (at the specified point or points) the (specified type of) sound pressure level shall be measured in accordance with ANSI S1.13-2005."

American National Standard

Measurement of Sound Pressure Levels In Air

1 Scope

This standard specifies requirements and procedures for the measurement of sound pressure levels in air. These requirements and procedures apply primarily to measurements performed under normal, relatively quiescent meteorological conditions. Nearly all measurements made indoors will fall under such conditions, but outdoor measurements may also be made, and may remain in conformance with this standard provided the ranges of certain environmental variables are restricted, as described herein.

The requirements in this standard (identified by the use of the word *shall)* are to be understood as conditions on the measurements that must be met in order to state that such measurements have been made in conformance with this American National Standard. The guidelines and recommendations (identified by the use of the word *should)* are to be understood as conditions that will generally improve the accuracy, validity, applicability, documentation, and reporting of the measurement data but that are not mandatory for conformance.

The type of sounds considered by this standard may differ widely in temporal and spectral characteristics. The sound to be measured may be continuous or intermittent; it may be steady, fluctuating, or impulsive; and it may be essentially broad band or contain discrete tones or narrow bands of noise.

The frequency range covered by the requirements of this standard depends on the specific type of sound level meter or instrumentation being used, but, in general, the frequency content of the sound being measured should be contained within the range covered by the octave bands having center frequencies from 31.5 Hz to 16.0 kHz. The sound pressure levels of sounds whose energy is concentrated outside of this range may not be measured accurately according to the procedures of this standard.

The sound pressure level descriptors primarily used in this standard are the time-average A-weighted sound level (also called the equivalent-continuous A-weighted sound pressure level) and the A-weighted sound exposure level. The choice of descriptor and the measurement procedures to follow depend on the type of sound, and this standard gives requirements and guidelines governing this choice.

The nature of the sound that is being measured by the procedures of this standard may be considered as either *desirable* (e.g., music from a symphony orchestra or a signal from an alarm device) or *undesirable* (e.g., noise from a busy highway or household vacuum cleaner). There is no differentiation as far as the procedures in this standard are concerned.

This standard does not address the measurement of sound pressure levels in environments other than air (such as other gases, liquids, or solids), the measurement of infrasonic or ultrasonic sounds, or (generally) the measurement of sound pressure levels outdoors in nonquiescent conditions.

2 Purpose

This standard has a number of purposes, equally important. They are as follows:

a) To establish uniform procedures for measuring the sound pressure level in air at a single point in space.

b) To provide a classification of the types of sounds that can occur.

c) To facilitate the drafting of test codes, regulations, and the like by standardizing the basic requirements of sound pressure level measurements common to most of these documents. Rather than reiterating these requirements, the test codes and similar documents may simply refer to ANSI S1.13-2005 for the essential requirements.

d) To help make the procedures of acoustical measurements more accessible to regulatory personnel and the general public through clearly defining the steps and types of instrumentation necessary.

3 Applications

Since this is a fundamental standard, as opposed to a specialized standard or test code, it is applicable to the acquisition of sound pressure level data by a wide range of interested parties for a wide range of purposes. To illustrate just a few possible applications, this standard may be used:

- By an individual who wishes to know the sound pressure level at a certain point in or around the home, at a concert, or at a work environment.

- To assess the change in sound pressure level at a certain point due to the switching on or off of a particular sound source.

- To assess whether or not a certain acoustical space, such as an office, conference room, or concert hall, meets a particular background noise specification.

- In conjunction with other standards and procedures, to assess hearing-damage risk caused by noise exposure.

- By law-enforcement agents, usually in conjunction with another standard or procedural document, to assess compliance with noise regulations.

- By manufacturers, in conjunction with applicable noise emission standards or test codes, to determine the sound power level of a product.

- By testing laboratories, in conjunction with other standards, to check whether or not stated noise emission levels are verified.

- To evaluate the performance of loudspeakers, musical instruments, or other sound sources.

4 Normative references

The following Standards contain provisions which, through reference in this text, constitute provisions of this American National Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this American National Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

ANSI S1.4-1983 (R 2001), *American National Standard Specification for Sound Level Meters*. Includes S1.4A-1985 (R 2001), American National Standard Specification for Sound Level Meters (Amendment).

ANSI S1.11-2004, *American National Standard Specifications for Octave-Band and Fractional Octave-Band Analog and Digital Filters*.

ANSI S1.40-1984 (R 1997) *American National Standard Specifications for Acoustical Calibrators*.

ANSI S1.42-2001 *American National Standard Design Response of Weighting Networks for Acoustical Measurements*.

ANSI S1.43-1997 (R 2002), *American National Standard Specifications for Integrating-Averaging Sound Level Meters*.

ANSI S12.7-1986 (R 1998), *American National Standard Methods for Measurement of Impulse Noise*.

ANIS S12.9-1988/Part 1 (R 2003), *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 1*.

ANSI S12.9-1992/Part 2 (R 2003) *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 2: Measurement of Long-Term, Wide-Area Sound*.

ANSI S12.9-1993/Part 3 (R 2003), *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 3: Short-term Measurements with an Observer Present*.

ANSI S12.9-1996/Part 4 (R 2001), *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 4: Noise Assessment and Prediction of Long-Term Community Response*.

ANSI S12.9-1998/Part 5 (R 2003), *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 5: Sound Level Descriptors for Determination of Compatible Land Use*.

ANSI S12.9-2000/Part 6, *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 6: Methods for Estimation of Awakenings Associated with Aircraft Noise Events Heard in Homes*.

ANSI S12.18-1994 (R2004), *American National Standard Procedures for Outdoor Measurement of Sound Pressure Level*.

5 Definitions

5.1
ambient sound
The all-encompassing sound existing at a specified point and time associated with a given environment. The ambient sound is usually a composite of sounds from several sources, near and far.

NOTE 1 In general, the ambient sound may include sounds from individually identifiable sources that operate continuously. The sound from such a source at a specified point and time in the given environment is sometimes referred to as the specific sound.

NOTE 2 The ambient sound may be reduced in level by eliminating one or more of the individually identifiable sources. When all such sources can be eliminated, the resulting sound at a specified point and time in the given environment is sometimes referred to as the residual sound.

NOTE 3 If sounds from intermittent sources contribute to the overall ambient sound at a given point in an environment (such as the low-level sounds of passing cars on a distant roadway), the level of the ambient sound should be taken as the level in the absence of such intermittent events, if practical.

5.2
sound of interest
The sound existing at a specified point in a given environment that is intended to be characterized (by the methods of this standard). The sound of interest may be the ambient sound itself, or it may be a sound

that is clearly distinguishable from the ambient sound. The source or sources of the sound of interest may or may not be identifiable.

NOTE Examples of sounds of interest are the sound inside a classroom next to a highway, the sound existing at a residential property line when a nearby fire station siren goes off, the sound of a passing vehicle at a certain distance from the roadway, and the sound in the center of a concert hall during a symphony.

5.3
observation period
The time period during which the sound of interest is observed, measured, recorded, or otherwise assessed for the purposes of classifying the type of sound in regard to its temporal or spectral characteristics.

5.4
measurement time interval
The time interval over which the squared instantaneous sound pressure is integrated to compute the time-averaged sound pressure or the sound exposure (i.e., the time interval during which data are actually measured).

5.5
instantaneous sound pressure
The sound pressure (i.e., the difference between the total pressure and the atmospheric static pressure) that exists at a given point in space, at a particular instant in time, in a stated frequency band. Unit: pascal (Pa); symbol: $p(t)$.

NOTE The instantaneous sound pressure may be frequency-weighted by a standardized frequency-weighting characteristic (e.g., A or C, see ANSI S1.4-1983 and ANSI S1.4A-1985). Example: A-weighted instantaneous sound pressure; symbol: $p_{\mathrm{A}}(t)$.

5.6
peak sound pressure
At a point in space, the highest absolute value of the instantaneous sound pressure occurring during a specified time interval. Unit: pascal (Pa); symbol: P_{pk}.

NOTE The peak sound pressure may be frequency-weighted by a standardized frequency-weighting characteristic (e.g., A or C; see ANSI S1.4-1983 and ANSI S1.4A-1985). Example: A-weighted peak sound pressure; symbol: p_{Apk}.

5.7
peak sound pressure level
Ten times the common logarithm of the square of the ratio of the peak sound pressure to the reference sound pressure of 20 micropascals. Unit: decibel (dB); symbol: L_{pk}.

5.8
sound pressure
At a point in space, the root mean square determined over a specified time interval of the instantaneous sound pressure. Unit: pascal (Pa); symbol: p.

NOTE The term *sound pressure* is also used generically to mean the fluctuating pressure that is superimposed on the atmospheric static pressure due to the presence of a sound wave. However, in this standard, it has the restricted meaning, noted above.

5.9
sound pressure level
Ten times the common logarithm of the square of the ratio of the sound pressure to the reference sound pressure of 20 micropascals. Unit: decibel (dB); symbol: L_p.

Sound pressure level is given by the formula

$$L_p = 10 \quad \log_{10}\left(\frac{p}{p_0}\right)^2,$$

where

p is the sound pressure,

p_0 is the reference sound pressure of 20 μPa.

5.10
time-averaged A-weighted sound pressure
Square root of the time integral of squared A-weighted instantaneous sound pressure divided by the time period of integration in seconds. Unit: pascal (Pa); symbol: $\overline{p_{\mathrm{A}}}$.

The time period of the integration (averaging time) shall be specified. The time-averaged A-weighted sound pressure is given by the formula

$$\overline{p_{\mathrm{A}}} = \left(\frac{1}{(t_2 - t_1)}\int_{t_1}^{t_2} p_{\mathrm{A}}^2(t)dt\right)^{1/2},$$

where

$\overline{p_{\mathrm{A}}}$ is the time-averaged A-weighted sound pressure,

$p_{\mathrm{A}}^2(t)$ is the squared A-weighted instantaneous sound pressure.

NOTE 1 The frequency weighting should always be stated. If a frequency weighting besides A-weighting is used (e.g., C-weighting), it should be stated explicitly in the title (e.g., time-averaged C-weighted sound pressure; symbol: $\overline{p_{\mathrm{C}}}$).

NOTE 2 If no frequency weighting is used and the time-averaged sound level is measured in a frequency band (such as an octave band or one-third octave band), the frequency band should be specified.

5.11
time-averaged A-weighted sound level
Ten times the common logarithm of the square of the ratio of time-averaged A-weighted sound pressure to the reference sound pressure of 20 micro-pascals. Unit: decibel (dB), symbol: $L_{\mathrm{A},T}$.

NOTE 1 The time-averaged A-weighted sound level is the primary quantity measured by many commercially available sound level meters. Performance requirements for sound level meters are specified in ANSI S1.4-1983 and ANSI S1.4A-1985.

NOTE 2 The time-averaged A-weighted sound level is also termed the equivalent continuous A-weighted sound pressure level.

NOTE 3 The frequency weighting should always be stated. If a frequency weighting besides A-weighting is used (e.g., C-weighting), it should be stated explicitly in the title (e.g., time-averaged C-weighted sound level; symbol: $L_{C,T}$). If no frequency weighting is used and the time-averaged sound level is measured in a frequency band (such as an octave band or one-third octave band), the frequency band should be specified.

NOTE 4 Long-term, cumulative average sound pressure level descriptors for rating environmental sound and determining compatible land use are given in ANSI S12.9.

5.12
A-weighted sound exposure
Time integral of the squared instantaneous A-weighted sound pressure over a given time interval. Unit: pascal-squared second (Pa^2s); symbol: E_A. The A-weighted sound exposure is given by the formula

$$E_A = \int_{t_1}^{t_2} p_A^2(t)dt,$$

where

E_A is the A-weighted sound exposure determined over a time interval (t_2–t_1),

$p_A^2(t)$ is the squared A-weighted instantaneous sound pressure.

NOTE 1 The frequency weighting should always be stated. If a frequency weighting besides A-weighting is used (e.g., C-weighting), it should be stated explicitly in the title (e.g., C-weighted sound exposure; symbol: E_C).

NOTE 2 If no frequency weighting is used and the time-averaged sound exposure is measured in a frequency band (such as an octave band or one-third octave band), the frequency band should be specified.

5.13
A-weighted sound exposure level
Ten times the common logarithm of the ratio of the A-weighted sound exposure to the reference sound exposure (symbol: E_0) of 400 micropascal-squared seconds (400 μPa^2 s). Unit: decibel (dB); symbol: L_{AE}.

NOTE 1 The sound exposure level is capable of being measured directly by many commercially available sound level meters.

NOTE 2 For a single-event sound, such as an aircraft flyover, the integration time interval should encompass all significant sound associated with the event.

NOTE 3 The frequency weighting should always be stated. If a frequency weighting besides A-weighting is used (e.g., C-weighting), it should be stated explicitly in the title (e.g., C-weighted sound exposure level; symbol: L_{CE}). If no frequency weighting is used and the time-averaged sound exposure is measured in a frequency band (such as an octave band or one-third octave band), the frequency band should be specified.

NOTE 4 Long-term, cumulative sound exposure level descriptors for rating environmental sound and determining compatible land use are given in ANSI S12.9.

5.14
impulse
A transient excursion in sound pressure amplitude such that (i) the duration of the excursion is less than 1 s, (ii) the peak sound pressure level during the excursion is at least 10 dB above the sound pressure level of the ambient sound, and (iii) either the rise time or fall time, or both, from the peak level to the ambient level is less than 250 ms. The ambient level is taken as the sound pressure level that would exist in the absence of the impulse, and the duration of the impulse is taken as either (i) the time interval that the instantaneous sound pressure of the impulse exceeds that of the ambient or (ii) the time interval between the points on the rising and trailing edges of the impulse that are 20 dB below the peak level, whichever time interval is shorter.

6 Types of sound

The type of sound that exists at a point in a sound field can be classified according to its temporal characteristics (how it varies with time) and its spectral characteristics (how it varies over frequency). The following paragraphs are intended to provide guidance in classifying the sound to be measured and should be taken as definitions for the purposes of this standard.

NOTE Most of the time, the sound may be properly classified by simply listening to the sound at the measurement point. If there is doubt, the sound level meter or other instrument that will be used for the measurements may be helpful in the classification.

6.1 Temporal characteristics

The sounds usually encountered in practice may be broadly classified as being either *continuous* or *intermittent* in their temporal characteristics. Within each of these two categories, and during the time interval that the sound is actually "on" at the measurement point, it may be further classified as either steady, fluctuating, or impulsive.

The temporal characteristics of the sound of interest shall be classified according to one of the paragraphs in either Sec. 6.1.1 or 6.1.2.

6.1.1 Continuous sound. At a specified point in the given environment, a sound whose sound pressure level remains above that of the ambient sound during the observation period.

NOTE 1 The ambient sound itself is always taken to be continuous. Therefore, if the sound of interest is the ambient sound itself, it is classified as continuous sound.

NOTE 2 In some instances, it may be useful to use a threshold other than that of the level of the ambient sound in order to classify whether or not a given sound is continuous. In such cases, the threshold should be stated.

6.1.1.1 Steady continuous sound. Continuous sound whose sound pressure level remains essentially constant during the observation period.

NOTE 1 A continuous sound may be considered steady if either its time-averaged A-weighted sound level over a one second integration period ("short-term time-averaged sound level" or "short-term L_{eq}") or its A-weighted sound level measured with the slow exponential time weighting does not vary by more than ±3 dB about its mean level over the observation period.

NOTE 2 Certain sounds that are characterized by "stepwise" variations in levels may also be considered steady provided that the level during each step meets the condition in Note 1 above when the observation period is equal to the duration of each stepwise variation (see also Sec. 9.4.1.1).

NOTE 3 Examples of steady continuous sounds are the noise from fans and blowers, the hum of a transformer, and the noise inside a car or truck moving at constant speed over a uniform roadway. An example of a steady continuous sound that varies in a stepwise manner is that near a paint-drying area of a factory where first one air dryer is running, and then two, and then perhaps four, then back to one, etc.

6.1.1.2 Fluctuating continuous sound. Continuous sound whose sound pressure level varies significantly, but not in an impulsive manner, during the observation period.

NOTE 1 A continuous sound may be considered fluctuating if either its time-averaged A-weighted sound level over a one second integration period ("short-term time-averaged sound level" or "short-term L_{eq}") or its A-weighted sound level measured with the slow exponential time weighting varies by more than ±3 dB about its mean value over the observation period.

NOTE 2 Examples of fluctuating continuous sounds are the noise from bulldozers and backhoes during grading operations; the sound of gusting wind rustling through leaves, or waves striking a beach; and the noise from a lawn mower traversing a neighbor's yard.

6.1.1.3 Impulsive continuous sound. Continuous sound containing one or more impulses during the observation period.

NOTE 1 A sound containing a train of impulses, each separated in time by less than 1 s, may be considered impulsive continuous sound even if its sound pressure level falls to or below that of the ambient sound during the observation period.

NOTE 2 Examples of impulsive continuous sounds are the noise from a dot-matrix printer (during the time it is printing), the noise from a jackhammer (during the time it is hammering), and the sound of a marching band or most other music containing percussion instruments.

6.1.2 Intermittent sound. At a specified point in the given environment, a sound whose sound pressure level equals or drops below that of the ambient sound at least two times during the observation period.

NOTE In some instances, it may be useful to use a threshold other than that of the level of the ambient sound in order to classify whether or not a given sound is intermittent. In such cases, the threshold should be stated.

6.1.2.1 Steady intermittent sound. Intermittent sound whose sound pressure level remains essentially constant during the time interval that it is above the ambient level.

NOTE 1 An intermittent sound may be considered steady if either the time-averaged A-weighted sound level over a 1 s integration period ("short-term time-averaged sound level" or "short-term L_{eq}") or its A-weighted sound level measured with the slow exponential time weighting does not vary by more than ±3 dB about its mean level during the time interval that the sound is above the ambient level.

NOTE 2 Examples of steady intermittent sounds are the noise from factory machines performing certain repetitive actions such as filling bottles, sawing boards, or drilling holes; the sound from a distant foghorn; and the noise from many business machines such as copiers, FAX machines, and laser printers.

6.1.2.2 Fluctuating intermittent sound. Intermittent sound whose sound pressure level varies significantly, but not in an impulsive manner, during the time interval that it is above the ambient level.

NOTE 1 An intermittent sound may be considered fluctuating if either the time-averaged A-weighted sound level over a 1 s integration period ("short-term time-averaged sound level" or "short-term L_{eq}") or its A-weighted sound level measured with the slow exponential time weighting varies by more than ±3 dB about its mean level during the time interval that the sound is above the ambient level.

NOTE 2 Examples of fluctuating intermittent sounds are the noise from aircraft flyovers; passing motor vehicles or railway cars; the cheering of a large crowd at a sport event; and the sound inside a hotel room next to an elevator.

6.1.2.3 Impulsive intermittent sound. Intermittent sound containing one or more impulses during the time interval that its sound pressure level is above that of the ambient level.

NOTE 1 A sound comprising a single impulse is considered an impulsive intermittent sound.

NOTE 2 Examples of impulsive intermittent sounds are explosions or sonic booms (single impulses), the noise from an impact printer printing more than one line, the sound of artillery fire or fireworks displays, and the sound from a old-style ringing telephone.

6.2 Frequency characteristics

The sounds usually encountered in practice may be classified as either broad-band sounds, narrow-band sounds, or discrete tones. The total sound at a given point in space may be a combination of any of these. The frequency characteristics of the sound of interest shall be classified according to one of the sections below.

6.2.1 Broad-band sound. A broad-band sound is one in which the acoustical energy is distributed over a relatively wide range of frequencies. The spectrum of such a sound (e.g., a plot of sound pressure amplitude as a function of frequency) will be generally smooth and continuous, although it may vary quite a bit from "flat." If the broad-band sound does not contain any significant discrete tones, the sound will lack a subjective quality of pitch or tonality.

NOTE Examples of broad-band sounds without discrete tones are the sound of a waterfall, the noise from an air diffuser outlet in a typical room, and the noise from a highway.

6.2.2 Narrow-band sound. A narrow-band sound is one in which the acoustical energy is concentrated in a relatively narrow range of frequencies. The spectrum of such a sound will show a localized "hump" or peak in amplitude. Narrow-band sound may be superimposed on broad-band sound. If the narrow-band sound does not contain any significant discrete tones, the sound will generally lack a subjective quality of pitch or tonality.

NOTE 1 Narrow-band sound is not very common in practice, but when it does occur it is usually recognizable as such by simple listening. When narrow-band sound is present in combination with broad-band sound, which would result in a broad-band spectrum containing one or more localized humps, it may be difficult to identify it as such with just the human ear.

NOTE 2 Examples of narrow-band sounds without discrete tones are the sound of distant thunder (low frequency), the sound of wind gusting over a prairie or through a canyon (middle frequency), and the sound of an air leak in an automobile tire (high frequency).

6.2.3 Discrete tones. A discrete tone is a periodic sound pressure variation that gives rise to the sensation of pitch. It can be either a purely sinusoidal variation (sometimes called a *pure tone),* in which case the frequency spectrum would show a single "spike" at the sinusoidal frequency, or, more typically, a nonsinusoidal variation, in which case the spectrum would show a spike at the fundamental frequency and other spikes at harmonics (integer multiples) of the fundamental.

NOTE Examples of discrete tones are the hum of a transformer, a beep from a digital instrument, a smoke alarm going off, and a note played on a musical instrument.

6.2.4 Broad-band sound containing discrete tones. This is given as a separate entry because it represents probably the most common type of sound and is usually caused by a sound source that is either vibrating or rotating at a periodic rate. The spectrum of this type of sound is essentially that of the underlying broad-band sound with one or several sharp spikes corresponding to the tone or tones and their harmonics. The tonal components are audible to varying degrees depending on the relative level of the tones compared to the broad-band sound. If the tones are clearly audible, they may be classified as "prominent" (see Annex A).

NOTE Examples of broad-band sounds containing discrete tones are the noises from household appliances such as vacuum cleaners, blenders, and hair dryers; small fans used to cool electronics; and a dentist's drill.

6.3 Spatial characteristics

In some cases the sound of interest being measured may also be classified according to its spatial characteristics, that is, how the level varies from one point to another in the sound field. This standard, however, does not require that a classification be made of the spatial characteristics of the sound field. Often this is a difficult task, and just as often the spatial characteristics are not relevant or applicable. However, if such a classification can easily be made and it is relevant or useful, it is recommended that a statement be included in the report.

For example, if the sound pressure level in a classroom is of interest due to the noise from a nearby outdoor air-conditioning unit, it would be worth noting whether or not the level was relatively constant around the classroom. On the other hand, if the sound pressure level at a single position is desired, such as the operator's position for a certain machine, the spatial variation is usually not important.

7 Types of acoustical environment

The type of acoustical environment in which the sound pressure level measurements are made shall also be classified or described. Those physical aspects that affect the acoustical environment are of interest, of course, and those aspects that have no bearing on the latter (such as the color of walls, etc.) need not be included. If there is doubt whether or not a particular physical feature of the environment affects the sound field, it should be included in the description. The following ideal and practical acoustical environments are described to provide guidance in classifying the measurement environment.

7.1 Ideal acoustical environments

7.1.1 Free sound field. Ideally, a sound field totally free of reflecting boundaries or obstacles. In practice, it is a sound field in which reflections from the boundaries and obstacles are negligible over the frequency range of interest. In general, the sound pressure level due to an isolated source in a free sound field will decrease at a rate of 6 dB per doubling of distance from the source, except when very close to the source.

7.1.2 Free sound field over a reflecting plane. Ideally, a sound field free of reflecting boundaries and obstacles in the half space above an infinite, totally reflecting plane surface. In practice, it is a sound field in which reflections from boundaries and obstacles except a single, extended, hard surface (such as an asphalt parking lot) are negligible over the frequency range of interest. In general, the sound pressure level due to an isolated source in a free sound field over a reflecting plane will decrease at a rate of 6 dB per doubling of distance from the source, except when very close to the source.

NOTE Due to the reflecting surface, the measured sound pressure level at a point in a free sound field over a reflecting plane is, in general, 3 dB higher than in a free sound field (assuming the measurement is at the same distance and geometrical orientation from the same isolated sound source whose sound power output is constant.)

7.1.3 Diffuse field. Region of a sound field that has a statistically uniform energy density and in which the directions of propagation are randomly distributed. The sound pressure level is constant throughout the region and does not vary with microphone orientation.

7.2 Practical acoustical environment

Usually, the real environment is somewhere "in between" these ideal environments and the report should attempt to describe the acoustical environment in as much detail as possible. (Photographs of the area are useful for documentation purposes.)

7.2.1 Indoors. A relatively small room with hard walls and several sound sources might approximate a diffuse field, yet a very large room with measurements being taken close to an isolated sound source might approximate a free sound field over a reflecting plane. Preliminary measurements at several points in the sound field may be helpful in classifying the type of acoustical environment (i.e., is the level relatively constant or does it decrease with distance from a particular source?). In general, the size and shape of the indoor area should be given, as well as a description of the surfaces and major objects in the room.

7.2.2 Outdoors. Large, flat, open outdoor areas such as parking lots approximate a free sound field over a reflecting plane for an isolated source and low ambient noise levels, but if large reflecting walls or obstacles are present or there are several sources or high ambient levels, this is no longer true, and the 6 dB per doubling of distance behavior will not be realized. It is important to note the presence of large reflecting objects. The type of terrain and topography should also be described. (Again, photographs of the measurement area would be useful.)

8 Instrumentation for measuring sound pressure levels

8.1 General requirements

The accuracy of a sound pressure level measurement depends not only on the accuracy and reliability of the instrumentation but on how it is used. For example, even if one has properly selected a sound level meter meeting the requirements of this or another standard, if a signal being measured is too high for the particular range selected, the instrument will overload and display an inaccurate result. Similarly, if the signal being measured is too low for the particular range, the measurement may be corrupted by the internal noise of the instrument, again giving an inaccurate result. Although this standard gives guidance on some of the more important aspects of taking a proper reading, the manufacturer's instructions for the particular sound-measuring instruments being used should be studied and followed. It is a requirement of this standard that the person or persons operating the sound level meter or other sound-measuring instrumentation shall be familiar with the manufacturer's instructions for proper usage.

8.2 Sound level meters

Most likely, the majority of measurements of sound pressure level made according to this standard will be taken with a commercially available sound level meter. Although in principle, any combination of instruments and equipment assembled for the measurement and display of sound pressure level can be termed a sound level meter, the term is usually reserved for the type of instrument that has all the necessary components self-contained in a single unit. The principal components of *a* sound level meter include a microphone, preamplifier, amplifier, frequency-weighting circuitry, attenuators and range controls, time-averaging circuit, and a display or indicating device. There may also be connections or outputs for external frequency filters, such as octave-band or one-third octave-band filters (or such filters may be integral to the unit), analog and digital outputs, and other special features. Descriptions of these components may be found in the manufacturer's operating manual, basic texts on acoustics, and other standards on sound level meters. At the present time, there are two types of sound level meters in common usage: integrating-averaging sound level meters and so-called conventional sound level meters. The method of time averaging is what differentiates the two types. The integrating-averaging sound level meter is the newer of the two types and is becoming more and more common in general practice. Conventional sound level meters date from the 1930s but are still being used and manufactured today, although at a diminishing rate. The preferred instrument for use by this standard is the integrating-averaging sound level meter, but conventional sound level meters are included for completeness.

NOTE Users should be aware that some of the existing published noise-evaluation criteria (such as damage risk criteria) were established many years ago based on measurements taken with vintage instrumentation (perhaps employing different reference values) and manual methods (such as manual sampling and statistical procedures). Prudence should be exercised when comparing data taken with modern sound-level instrumentation to these older criteria, particularly in the case of noise exposure levels (noise dose).

8.2.1 Integrating or intergrating–averaging sound level meters. Integrating–averaging sound level meters (or simply "integrating sound level meters" or "averaging sound level meters") are capable of measuring and computing the time-averaged A-weighted sound level defined in Sec. 5.11 and the A-weighted sound exposure level defined in Sec. 5.13. These sound level meters shall comply with the performance and electrical requirements of ANSI S1.43-1997. ANSI S1.43 defines three precision "types" of sound level meters, types 0, type 1, and 2, with type 0 having the narrowest performance tolerances and type 2 having the widest. Sound level meters used in accordance with this standard should preferably meet type 1 requirements, but shall at least meet type 2 requirements. The type designation of the sound-level meter used for the measurements shall be indicated.

NOTE Most modern, commercially available integrating-averaging sound level meters will meet the requirements of ANSI S1.43 and the type designation will clearly be indicated by the manufacturer.

8.2.2 Conventional sound level meters. These are an older type of sound level meter, based upon analog *RC* circuitry that performs an exponential, "running" average to approximate the rms sound pressure level. Performance requirements of conventional sound level meters are specified in ANSI S1.4. Two time constants are standardized: "slow" with a time constant of 1 s and "fast" with a time constant of 125 ms. In addition, an "impulse" time-weighting characteristic is also defined, having a 35-ms rise time and a 1.5-s decay time. As mentioned above, the preferred instrument in this standard for all types of sounds, including impulsive sounds, is the integrating-averaging sound level meter. However, if a conventional sound level meter is used (e.g., for steady sounds; see Secs. 9.4.1 and 9.4.2), it shall comply with the performance and electrical requirements of ANSI S1.4-1983, preferably meeting type 1 requirements but at least meeting type 2 requirements. The type designation of the sound level meter used for the measurements shall be indicated.

8.3 Component systems

Sometimes the "sound level meter" will consist of separate components rather than being self-contained in a single instrument. For instance, the microphone may be mounted on a stand with a long cable attaching it to a power supply, from which the signal is fed to a separate amplifier with an integral or external A-weighting circuit, and then to a separate instrument to perform the integration–averaging and display. If this is the case or if other types of specialized instrumentation are assembled as a sound pressure level measuring system, the overall "instrument" from microphone to display shall meet the requirements of ANSI S1.43-1997 and S1.4-1983. Where specifications are given in these standards for individual components, such as the microphone and display, these requirements shall also be met by the individual components of the measurement system.

8.4 Frequency weightings

A-weighting is the preferred frequency weighting for all measurements made in accordance with this standard, and the characteristics of this weighting network shall comply with those specified in ANSI S1.4-1983. If C-weighting is used, it shall also be in conformance with ANSI S1.4-1983. If D-weighting or E-weighting are used, they should comply with the specifications in ANSI S1.42-2001.

8.5 Octave-band and one-third octave-band analyzers

If a frequency analysis of the measured sound of interest is desired, it is recommended that this be performed on a one-third octave-band basis. An octave-band analysis may be performed as a less preferable alternative, but other fractional octave-band analyses should be avoided or only used to supplement these. The one-third octave-band or octave-band filters shall meet the requirements of ANSI S1.11-2004 for order 3 or higher-order filters.

NOTE 1 Most modern, commercially available one-third octave-band and octave-band filter sets will meet the requirements of ANSI S1.11, and the manufacturer will most likely state the order number of the filters.

NOTE 2 If the sound of interest being measured contains discrete tones, it is recommended that a fast Fourier transform (FFT) be performed, if practical, to identify the precise frequency and level of the tone or tones. However, at present there are no standards governing the specifications of these instruments, so the manufacturer's instructions should be followed carefully.

8.6 Data-logging and data-sampling instruments

There are a variety of commercially available devices designed to obtain periodic samples of the time-varying sound pressure level existing at the measurement point. These devices function as statistical distribution analyzers and are usually employed to determine the so-called "percentile levels" of the sound of interest (e.g., see ANSI S12.9), but may also be used to compute the A-weighted time-averaged sound pressure level, which is the preferred descriptor in this standard. If such instruments are used, they shall meet the requirements on sound level meters given in Sec. 8.2.1 or 8.2.2, as appropriate. When using such instruments, the manufacturer's operating instructions shall be followed and the discrete sound level *bins* (or *class intervals)* shall be chosen based on the overall range of the sound pressure levels, but shall not exceed 5 dB.

8.7 Equipment for recording and storing data

It is sometimes desirable to record the sound of interest at the measurement position in the field for later analysis in the laboratory. Care should be exercised when using this option, as there are several factors, some of which are discussed below, that can cause the recorded signal to deviate from the actual signal existing in the field at the microphone. The most common type of recording device in use today is the magnetic tape recorder, but more modern techniques involving direct recording of digitized signals onto magnetic or optical disks are also available. If a magnetic tape recorder is to be used, it is recommended that it be of a digital type, such as a digital audio tape (DAT) recorder or a pulse code modulation (PCM) recorder. If an analog tape recorder is used, it should be of high quality, such as an instrumentation-grade recorder.

Owing to the wide variety of available recording equipment and techniques, it is difficult to establish actual requirements for the instrumentation or procedures other than the few given below. However, it shall be taken as a requirement of this standard that the operator of the recording equipment shall be knowledgeable with respect to its operation and performance capabilities and limitations.

8.7.1 Recording-equipment characteristics. The characteristics that are of critical importance in the choice of a recording device for sound-level measurements are the frequency response, the signal-to-noise ratio, and the speed stability. The frequency response shall be flat within ±3 dB over the frequency range 50-15 000 Hz. The signal-to-noise ratio (defined as the range from the internal-noise floor to the level where the recorded signal shows a total distortion of 2% or more) shall be at least 50 dB, and preferably greater than 70 dB. Speed fluctuations are usually only a problem with analog tape recorders, and in this case total wow and flutter shall not exceed 0.3%.

NOTE 1 Almost all small, portable, digital tape recorders commercially available meet and exceed these requirements. Speed fluctuation is not important with digital recorders; it has no effect on the reconstructed signal.

NOTE 2 The gain of the recorder must be adjustable and independent of the signal input level; that is, recorders with automatic gain control or automatic limiting circuitry must not be used.

NOTE 3 Only high-quality recording tape, where applicable, should be used, and the recorder should be adjusted for the specific tape being used.

8.7.2 Procedure for the use of recording equipment in the field. The manufacturer's procedures shall be followed for setting up the recording equipment and controlling the input gain and other controls for optimum results. The place in the instrumentation chain for selecting the signal to be recorded shall be prudently chosen and carefully noted: Is it taken directly from the microphone, after the input attenuators, after the A-weighting circuitry, etc.? This choice is governed by how the recorded signal will be subsequently analyzed in the laboratory. The recording level should be set based on a preliminary screening of the sound of interest to be measured and recorded. Care should be taken to ensure that the signal being recorded will neither be overloaded nor fall below the noise floor of the recording device at any time during the measurement time interval.

With the recording level selected and held fixed, a calibration signal from the microphone (see Sec. 9.2.2) shall be recorded that will allow subsequent correlation of the playback levels to the actual levels that existed during the measurements. Whenever it is necessary to adjust the input record level during the measurements, a new calibration signal shall be recorded.

If the recording device has more than one track or channel, it is recommended that voice comments and "start-stop" signals be recorded on a separate track from the data (e.g., for common two-channel recorders, the voice should be recorded on the right channel and the data on the left). However, if only a single channel is available, then voice and data may be mixed.

8.7.3 Qualification tests for the use of recording equipment. So that it can be demonstrated that sound pressure levels measured in the field or laboratory agree with those determined from subsequent analyses of the recorded signals, at least one of the two procedures given below shall be employed, preferably both.

8.7.3.1 Qualification at the time of measurement. This approach requires that both the recording equipment and a sound level meter be available in the field at the place of measurement. In addition to a calibration signal, the A-weighted time-averaged sound pressure level at a particular point in space and over a particular measurement time interval shall be measured while simultaneously recording the signal (using "start" and "stop" timing marks on the tape). The same microphone should be used for both the recorded and the *in situ* measurement. This shall be done at least at the start and end of the field measurements for cross-checking back at the laboratory. The precision of the agreement between actual and playback measurements will depend on the quality of the recording equipment, but if the differences in the A-weighted levels are greater than ±1.5 dB, the recording equipment shall not be considered adequate for the purposes of this standard.

8.7.3.2 Qualification in advance. This approach allows the recording equipment alone (in addition to a calibrator) to be taken into the field. A more complete qualification of the recording equipment shall be performed every six months to maintain a high level of confidence in the use of recordings for the measurements of sound pressure levels. This qualification can be performed in the laboratory itself. After recording a calibration signal, a test sound signal of interest shall be selected and a one-third octave-band or FFT analysis, or preferably both, shall be performed on the signal as it is simultaneously being recorded. A similar one-third octave-band or FFT analysis is then performed on the played-back signal using the same measurement time interval and start-stop positions and the spectra compared to the originals. The spectra should compare well over the frequency range covered by the one-third octave bands centered from 50 Hz to 10 000 Hz. The precision of the agreement between actual and playback spectra will depend on the quality of the recording equipment, but if the differences in any of the one-third octave bands (or in an equivalent FFT band one-third of an octave in width) are greater than ±3 dB, or if the differences in the A-weighted levels are greater than ±1.5 dB, the recording equipment shall not be considered adequate for the purposes of this standard. This qualification should be performed at various recording levels as a check on the linearity of the recording equipment.

9 Measurement of sound pressure level at a point in space

This section governs the actual measurement of the sound pressure level for various types of sound, from the planning and setup to the taking of data.

9.1 Planning and preparation for the measurements

9.1.1 Identifying the sound of interest. Before any measurements are made, exactly what is to be measured at the particular point in space should be clearly identified. As mentioned in the Introduction, the sound of interest can take many forms. It can be the total ambient sound existing at the measurement point or it can be the sound associated with a particular source. Often it is a combination of these, such as the change in ambient level at a particular location when a certain source is switched on or off. In any case, the sound of interest shall be clearly identified and described in the record of the measurements.

NOTE The sound of interest is defined for an individual sound pressure level measurement made at an individual point in space. For a series of such measurements, the sound of interest may differ for each (e.g., first the ambient alone, then the ambient plus source A, next the ambient plus source B, etc.).

9.1.2 Classifying the type of sound. Once the sound of interest has been identified, its temporal and frequency aspects shall be classified according to the definitions in Secs. 6.1 and 6.2. This classification is important because it governs what type of sound pressure level will be measured (e.g., time-averaged sound pressure level or sound exposure level), what measurement time interval should be chosen, and other aspects of the measurement itself. Most often the classification of the type of sound is an easy matter and can be performed quickly by listening to the sound of interest at the measurement position. However, sometimes it may be difficult to determine, for instance, whether or not the sound is intermittent or whether or not it is impulsive. Preliminary measurements or plots of the instantaneous or short-term time-averaged sound pressure level versus time over a sufficiently long observation period (see Sec. 5.3) may be helpful in classifying the type of sound. If applicable, the spatial aspects of the sound field should also be described, as discussed in Sec. 6.3.

9.1.3 Classifying the type of acoustical environment. The type of acoustical environment shall be described, as discussed in Secs. 7.1 and 7.2. Particular note shall be taken of the presence of large reflecting objects, significant terrain features, or other aspects that might affect the sound field at the microphone.

9.1.4 Devising a test plan. It is strongly recommended that a detailed test plan for the measurements be devised and documented beforehand to ensure that the actual data collection proceeds in an efficient, orderly, accurate, and complete manner. This will reduce the risk of operator errors, and will result in peace of mind during the measurements that all the desired information and data are covered (and will also avoid unnecessary return trips to the measurement site). Depending on the type and purpose of the measurements, the test plan may be simple or complex but should at least include the type of sound pressure levels to be measured; the instrumentation needed and any backup or auxiliary equipment or documentation that may be required (e.g., microphone windscreens, battery packs, meteorological measuring devices, operating manuals, etc.); whether or not one-third octave-band, FFT, or other frequency analysis will be performed; the proposed sequence of measurements, microphone positions and measurement time intervals; when and what type of calibrations will be performed; and whether or not the signals will be recorded.

9.2 Set-up for the measurements

9.2.1 Maintenance calibration of instruments. All equipment used in the measurement chain that can affect the indicated value of the sound pressure level shall be calibrated at regular intervals of time. Calibration time intervals are usually stated in the particular test code, standard, or regulation being followed in performing measurements of sound pressure level (if any). For instance, calibration intervals of one year for microphone calibrators and two years for sound level meters are commonly stated. In the absence of any stated calibration time intervals, a period of 2 years shall be taken as a requirement of this standard as the maximum interval for microphone calibrators and 3 years for sound level meters and other equipment used in the measurement chain that can affect the measured sound pressure levels. It is strongly recommended that these intervals be shortened to 1 year and 2 years, respectively.

9.2.2 Field calibration of instruments. In addition to periodic calibration of the instrumentation, a calibration "*field check*" of the acoustical sensitivity of the measurement system shall be made immediately before and immediately after a series of measurements. This field check shall be of either the self-contained sound level meter or of the overall sound level measuring system, as appropriate. When a single sound pressure level measurement or a series of measurements continues for a period of time longer than 12 hours, it is recommended that regular acoustical sensitivity checks be made at intervals not exceeding 12 hours. The sensitivity calibration shall be performed with a coupler type of sound level calibrator that meets the requirements of ANSI S1.40-1984. Several types are available commercially; the manufacturer's instructions shall be followed when performing this calibration.

If there are differences in noted sensitivity from one field calibration to the next, the system sensitivity or gain may be adjusted to bring the system back into calibration, but all such differences and adjustments shall be noted in the record and their potential effects on the precision of all results obtained between such adjustments shall be suitably considered. In any event, if the deviation in noted sensitivity between any two successive field checks exceeds 1.5 dB, all data obtained during that interval shall be discarded or at least flagged as not being in conformance with the requirements of this standard.

9.2.3 Meteorological conditions. Outdoor sound levels may be affected by meteorological conditions, especially when the distance from the microphone to the dominant source of sound is large. Measurements made in accordance with this standard are intended to be made under conditions where meteorological factors do not affect the measured results; i.e., indoors or outdoors under quiescent conditions. For general measurements of sound pressure levels outdoors, consult ANSI S12.18. In order for outdoor sound pressure level measurements to be considered in conformance with this standard, the wind speed at the measurement point and at all times during the measurement time interval shall not exceed 2 m/s. A suitable wind screen or nose cone approved by the manufacturer of the sound level meter or microphone shall be fitted over the microphone for all outdoor measurements, unless it can be shown in all one-third octave bands over the frequency range of interest that the sound of interest is at least 10 dB above the added noise due to the presence of any air movement past the microphone. Corrections for changes in microphone sensitivity for the windscreen or nose cone used during the measurements shall be applied to the observed sound pressure levels.

Measurements shall not be taken during precipitation. It is recommended that the relative humidity not exceed 80% and that the temperature be within the range from –10 °C and +50 °C, but in any case the relative humidity and temperature shall not be outside of the ranges recommended for operation by the manufacturers of the sound level meter or individual instruments in the measurement system.

9.2.4 Precautions to be observed

9.2.4.1 Overloading of instruments. Most sound level meters and similar instruments allow for selecting the range of the electronic circuitry and indicating meter to optimize the signal-to-noise ratio for the particular sound being measured. This is usually done by selecting or adjusting various knobs or pushbuttons. It is essential that the manufacturer's instructions be followed to avoid overloading the instrument during the measurement. (It is just as important to avoid "underloading," which would result in very poor signal-to-noise ratio).

9.2.4.2 Presence of operator during measurements. Reflections from the operator of the sound level meter may affect the measured levels. This is particularly true in sound fields approximating free sound fields or free sound fields over a reflecting plane (see Secs. 7.1.1 and 7.1.2). In highly reflective rooms or environments, this is not so critical. In general, however, it is recommended that the sound level meter be held away from the body of the operator (or other reflecting objects) to minimize the effects of reflections. If the sound of interest is from an identifiable source, then the sound level meter should be held away from the operator's body in such a way that the line between the operator and the meter is perpendicular to the line between the source and the meter. A microphone mounted on a tripod or stand and connected via an extension cable to the sound level meter is the ideal approach. (In this case, note that the field check sensitivity calibration must be performed with the extension cable in place.)

9.2.4.3 Very low or very high sound pressure levels. When very low sound pressure levels are to be measured, accurate readings are limited by the sound level meter's electrical noise floor. The manufacturer should state what this limit is, as a function of frequency, or at least give guidance on how it can be measured. Stray electrical fields can also affect low-level measurements and should be considered part of the noise floor when present. Sound pressure levels that are at least 10 dB higher than the electrical noise floor in each frequency band of interest can be measured relatively accurately while those that are less than 5 dB higher than the noise floor will not yield valid results.

When very high sound pressure levels are to be measured, precautions should be taken to ensure that spurious acoustical signals (called "micro-phonics") induced by mechanical vibrations of the microphone, cables, or other parts of the instrumentation chain do not affect the measured sound pressure levels. For most microphones or sound level meters, this does not become a problem until sound pressure levels are well above 100 dB. Solutions involve shock-mounting the microphone and cable, and the manufacturer may provide recommendations for this or other approaches.

9.2.5 Microphone position. This selection of the microphone position for measurement of the sound of interest will depend on the purposes of the measurement. Usually, when a particular test code or specific standard is being followed, the microphone position or positions will be defined therein. In the absence of any specified location for the microphone position, heights and positions in space are generally selected to correspond to those that the ears of human listeners would assume. For instance, if the sound of interest were that at the operator's position in front of a computer or machine tool, heights of 1.2 m for seated operators and 1.5 m for standing operators are generally employed. For general outdoor measurements, microphone heights of either 1.2 or 1.5 m above the ground are often used, and selected positions should be at least 3.5 m away from the nearest wall or large sound-reflecting object.

Although the procedures and requirements of this standard apply to an individual measurement at a single point in space, usually several of such individual measurements will be desired for the purposes at hand. Depending on the purpose of the overall measurement, a sufficient number of microphone positions should be selected to provide an adequate sampling of the sound field, as appropriate.

9.2.6 Microphone orientation. Most microphones used on sound level meters and those typically used in component sound pressure level measurement systems are essentially omnidirectional, so microphone orientation is not extremely critical. Since microphone characteristics do vary, however, it is recommended that the manufacturer's instructions be followed regarding orientation for specific measurement conditions and environments. Alternatively, when test codes, specific standards, or regulations are being followed, the microphone orientation will usually be defined therein. In the absence of any specific guidance, the following should be used to select microphone orientation.

(1) In any type of acoustical environment (free sound field, diffuse sound field, indoors, outdoors, etc.), if the sound of interest is predominantly coming from a single identifiable source (or several sources clustered together spatially, subtending a small angle to the microphone), then orient the microphone so that the line from the source (or the approximate center of the cluster) to the microphone forms a 70° angle with the axis of the microphone (e.g., start with the microphone pointing directly at the source and then rotate it up through an angle of 70°).

(2) In any type of acoustical environment (free sound field, diffuse sound field, indoors, outdoors, etc.), if the sound of interest is not associated with any particular source, or if it originates from sources spread out spatially, subtending a relatively large angle to the microphone, then orient the microphone so that it is pointing straight up.

NOTE At frequencies around 5–6 kHz, most microphones begin to become directional, and the directional effects increase with increasing frequency. However, since very few practical sounds or noise sources have their acoustical energies concentrated above 5 kHz, changes in microphone orientation will not usually result in significant changes in measured A-weighted sound pressure levels. If it is suspected that the sound of interest at the measurement point does contain significant high-frequency energy, or it is found that changing the orientation of the microphone causes resulting changes in the measured A-weighted level, then several orientations should be selected at the same measurement point and the results either reported separately or averaged.

If band sound pressure levels are being measured, orientation of the microphone can become a factor for some of the higher-frequency bands. The orientation should be controlled and documented, and, as above, several orientations may be selected and reported if the band levels vary significantly.

9.2.7 Determining the measurement time interval. The measurement time interval (see Sec. 5.4) depends on the type of sound to be measured and the purpose of the measurements. In general, it should be chosen so that all significant variations in level are covered. If the sound is repetitive or cyclical in nature, such as the cyclic operation of a copying machine, then the measurement time interval should include at least one complete cycle of the sound. In this case, it may be preferable that several complete cycles be included to obtain an accurate average, if appropriate. For long-duration cycles, the overall measurement time interval may be broken up into shorter contiguous time intervals.

If the sound of interest varies in a stepwise fashion, the measurement time intervals may be selected so that each corresponds to a particular step in overall variation.

If the sound of interest is transient or intermittent (such as a vehicle passing by), the measurement time interval should be chosen to include all significant portions of the signal for the measurement of sound exposure level.

9.3 Precision of measurements (measurement uncertainty)

In general, the measurement uncertainty associated with a single sound pressure level measurement at a point in space is difficult to quantify. There are many factors in addition to the accuracy and calibration condition of the instrumentation that affect the precision of the measurement. Usually, test codes and specialized standards dealing with the measurement of sound pressure levels or sound power levels under uniform and controlled conditions will attempt to define the degree of expected uncertainty associated with measurements made in accordance with these particular standards and test codes, but even then a series of preliminary inter-laboratory ("round robin") tests are usually necessary to establish the variability in the methods.

This standard does not attempt to define the precision of the measurements made in accordance with its requirements. In general, measurements made with higher precision instrumentation (e.g., a type 1 sound level meter instead of a type 2) will yield more precise results, but it is more likely that the type of sound being measured, the environmental conditions, and the experience and training of the operator will have a greater effect on measurement uncertainty than the precision of the instruments. However, with the goal of providing some insight to the user of this standard on the range of measurement uncertainty he or she can expect when following the requirements and heeding the precautions herein, the following broad characterization can be made. When measuring realistic sounds of interest, rarely will the uncertainty in the A-weighted time-average sound pressure level be greater than ±3–4 dB (even with a type 2 sound level meter), and seldom will it be less than 1 dB (even with a type 1 sound level meter).

NOTE The best way to reduce the effects of measurement uncertainty and to increase confidence in the stated results is to take several measurements of the same sound of interest at the same point in space (if the particular circumstances permit this) and average the results.

9.4 Measurement procedures

This section contains requirements and guidelines for the procedures involved in actually measuring the sound of interest at a point in space; i.e., in acquiring the sound pressure level data. It should be noted that most of the requirements and guidelines aimed at ensuring accurate and valid measurements should have already been met before one actually starts the measurement and that the acquisition of the data is a relatively simple process without many constraints.

As mentioned above, the preferred instrument for making measurements in conformance with this standard is the integrating–averaging sound level meter, and this type of instrument shall be used whenever practical. For certain types of sound, identified in the paragraphs below, a conventional sound level meter may be used, but even in these cases the integrating–averaging sound level meter is preferred and will provide greater accuracy.

For all measurements, the manufacturer's instructions for setting input levels, adjusting attenuators, or other actions aimed at optimizing the signal-to-noise ratio and avoiding overloads shall be followed.

For all of the paragraphs below, it is assumed that only (the preferred) A-weighted quantities are being measured. The procedures, however, are applicable to measurements using other frequency weightings or individual frequency bands.

NOTE Procedures for determining percentile levels (e.g., see ANSI S12.9) or for determining time-averaged sound pressure levels using so-called sampling techniques are not addressed in this standard. The use of percentile levels is diminishing and sampling techniques are not necessary with integrating-averaging sound level meters. However, there are instruments available commercially that perform sampling statistics automatically, and manual techniques are described in widely available texts and publications.

9.4.1 Steady continuous sound. For steady continuous sound (see Sec. 6.1.1.1), the time-averaged A-weighted sound level, as defined in Sec. 5.11, shall be measured. The measurement time interval shall be stated.

For this type of sound, a conventional sound level meter (see Sec. 8.2.2) may be employed, using the standardized A frequency weighting and slow exponential time weighting. The type of sound pressure level that is measured is then termed the A-weighted sound level to distinguish it from the time-averaged A-weighted sound level measured with an integrating-averaging sound level meter. The level shall be taken as the average (on a simple arithmetic basis) of the maximum and minimum levels indicated on the meter's display or scale during the measurement time interval. If the sound contains impulsive components, refer to Sec. 9.4.5

9.4.1.1 Steady continuous sound with stepwise variations in level. If the sound of interest is continuous but varies in a stepwise manner such that the level during each step may be classified as steady, then the sound pressure level can be measured as for steady continuous sound with the measurement time interval equal to the duration of each stepwise variation. The time interval and the time-averaged A-weighted sound level (or A-weighted sound level if a conventional sound level meter is used) shall be measured for each step. The overall time-averaged A-weighted sound level (or overall A-weighted sound level) for the overall duration of the sound may be computed by the formula

$$L_{\mathrm{A},T} = 10 \log_{10}\left(\frac{1}{T}\sum_{i=1}^{N} T_i 10^{0.1 L_{\mathrm{A},T_i}}\right),$$

where

L_{A,T_i} is the time-averaged A-weighted sound level (or A-weighted sound level) determined over each step time interval T_i,

$T = \sum_{i=1}^{N} T_i$ is the total measurement time interval,

N is the number of stepwise variations in level included in the measurement.

9.4.2 Steady intermittent sound. For steady intermittent sound (see Sec. 6.1.2.1) either the time-averaged A-weighted sound level, as defined in Sec. 5.11, or the A-weighted sound exposure level, as defined in Sec. 5.13, or both, shall be measured. The choice of which quantity to measure depends on the purpose and use of the measurements.

NOTE For example, an office copy machine operates on and off during the course of a business day and is classified as steady during the on periods. One may be interested in the time-averaged sound level at the operator's position over one particular on period or one may want to compare this level to the level of another on period. On the other hand, one may simply wish to know the overall time-averaged sound level for the entire series of periods during the day.

Alternatively, one may be interested in the sound exposure for the operator of the copier and may want to measure the sound exposure level for a particular on period or to compare the exposure from one on period to another. One may also want to determine the total sound exposure level over all the on periods for the day or to compare the exposures from one day to another.

For measurement of the time-averaged A-weighted sound level during one of the on periods of the intermittent sound of interest, treat this as steady continuous sound and refer to Sec. 9.4.1, including comments on conventional sound level meters and stepwise variations in level. The measurement time interval shall be stated and shall not include any of the off period of the sound.

The overall time-averaged A-weighted sound level for two or more of the on periods of the sound may be computed from the following formula:

$$L_{\mathrm{A},T} = 10\ \log_{10}\left(\frac{1}{T}\sum_{j=1}^{N} T_j 10^{0.1 L_{\mathrm{A},T_j}}\right),$$

where

L_{A,T_j} is the time-averaged A-weighted sound level (or A-weighted sound level) determined over each on period of the intermittent sound, T_j,

$T = \sum_{j=1}^{N} T_j$ is the total measurement time interval,

N is the number of on periods included in the determination of the time-average A-weighted sound level.

For measurement of the A-weighted sound exposure level of one of the on periods of the steady intermittent sound of interest, the measurement time interval shall encompass the entire on period and may generally include small portions of the off period (such as immediately before and immediately after the on period) with no discernible effect on the resulting sound exposure level.

The total sound exposure level for two or more of the on periods of the sound can be computed from the individual sound exposure levels from the following formula.

$$L_{\mathrm{A}E} = 10\ \log_{10}\left(\sum_{i=1}^{N} 10^{0.1 L_{\mathrm{A}E_i}}\right),$$

where

$L_{\mathrm{A}E_i}$ is the A-weighted sound exposure level of an individual on period of the steady intermittent sound,

N is the number of on periods included in the overall A-weighted sound exposure level.

9.4.3 Fluctuating continuous sound. For fluctuating continuous sound (see Sec. 6.1.1.2), the time-averaged A-weighted sound level, as defined in Sec. 5.11, shall be measured. The measurement time interval shall be stated. A conventional sound level meter may not be used.

9.4.4 Fluctuating intermittent sound. For fluctuating intermittent sound (see Sec. 6.1.2.2), the time-averaged A-weighted sound level, as defined in Sec. 5.11, the A-weighted sound exposure level, as defined in Sec. 5.13, or both, shall be measured. The choice of which quantity to measure depends on the purpose and use of the measurements. The signal between the start and end of the intermittent sound may be termed a *sound event* or simply an *event.*

NOTE Comments similar to those contained in the Note in Sec. 9.4.2 apply here also, except that here the sound of interest is not steady during each event (the on periods) but fluctuating. Instead of the office copier, the sound of interest might be the sound at an employee's desk due to aircraft flyovers during the course of a day.

For measurement of the time-averaged A-weighted sound level during an event of the fluctuating intermittent sound of interest, treat this as fluctuating continuous sound with the measurement time interval equal to the duration of the event and refer to Sec. 9.4.3.

The overall time-averaged A-weighted sound level for two or more sound events may be computed from the first formula in Sec. 9.4.2 (with *events* substituted for on *periods* in the terminology).

For measurement of the A-weighted sound exposure level of a single event of the fluctuating intermittent sound of interest, the measurement time interval shall encompass the entire event and may generally include small portions of the ambient sound immediately before and immediately after the event with no discernible effect on the resulting sound exposure level.

The total sound exposure level for two or more sound events can be computed from the individual sound exposure levels of the individual events from the second formula in Sec. 9.4.2 (with *events* substituted for *on periods* in the terminology).

The time-averaged A-weighted sound level of an individual sound event is related to the A-weighted sound exposure level by the following formula:

$$L_{\mathrm{A},T} = L_{\mathrm{A}E} - 10\log_{10}\left(\frac{T}{t_0}\right),$$

where

T is the time interval to which $L_{\mathrm{A},T}$ is referenced (usually equal to the duration of the event but in general may be different),

t_0 is the reference duration of 1 s.

9.4.5 Impulsive continuous sound. For impulsive continuous sound (see Sec. 6.1.1.3), the time-averaged A-weighted sound level, as defined in Sec. 5.11, shall be measured. The measurement time interval shall be stated.

Impulsive sounds may have relatively high peak amplitudes and very short durations (as short as 1 ms), and special care must be taken to ensure that the instrumentation is not overloaded. The integrating–averaging sound level meter is well suited for the measurement of impulsive sounds and is the preferred instrument.

If during the measurement time interval the impulsive sound of interest can be considered steady (see the Notes in Sec. 6.1.1.1), e.g., when many impulses of roughly the same level occur in rapid succession, a conventional sound level meter employing the I or "impulse" exponential time weighting (see ANSI S1.4) and A-weighting may be used for the measurements. The type of sound pressure level that is measured is then termed the AI-weighted sound level to distinguish it from the time-averaged A-weighted sound level measured with an integrating–averaging sound level meter. The level shall be taken as the average (on a simple arithmetic basis) of the maximum and minimum levels indicated on the meter's display or scale during the measurement time interval.

If during the measurement time interval, the impulsive sound of interest is considered fluctuating (see the Notes in Sec. 6.1.1.2), e.g., when the overall sound contains impulses that vary in level or isolated impulses, a conventional sound level meter shall not be used.

NOTE 1 Some integrating-averaging sound level meters are also equipped with the impulse time weighting and can measure what is termed the time-averaged AI-weighted sound level. See Appendix B of ANSI S1.43 and Annex B of this standard for more information.

NOTE 2 Care should be taken to ensure that any auxiliary devices that might be added to the measurement chain, such as preamplifiers or frequency filters, do not limit the ability of the instrumentation to measure short-duration sounds accurately.

9.4.6 Impulsive intermittent sound. For impulsive intermittent sound (see Sec. 6.1.2.3) the time-averaged A-weighted sound level, as defined in Sec. 5.11, the A-weighted sound exposure level, as defined in Sec. 5.13, or both shall be measured. For single impulses, such as explosions or sonic booms, the sound exposure level is usually the preferred descriptor, but the choice of which quantity to measure ultimately depends on the purpose and use of the measurements. The signal between the start and end of the intermittent sound, whether it contains a single or several impulses, may be termed a *sound event* or simply an *event.*

For measurement of the time-averaged A-weighted sound level during an event of the impulsive intermittent sound of interest, treat this as impulsive continuous sound with the measurement time interval equal to the duration of the event and refer to Sec. 9.4.5, including the comments on when a conventional sound level meter with I time weighting may be used.

The overall time-averaged A-weighted sound level for two or more sound events may be computed from the first formula in Sec. 9.4.2 (with *events* substituted for *on periods* in the terminology).

For measurement of the A-weighted sound exposure level of a single event of the impulsive intermittent sound of interest, the measurement time interval shall encompass the entire event and may generally include small portions of the ambient sound immediately before and immediately after the event with no discernible effect on the resulting sound exposure level.

The total sound exposure level for two or more sound events can be computed from the individual sound exposure levels of the individual events from the second formula in Sec. 9.4.2 (with *events* substituted for *on periods* in the terminology).

NOTE ANSI S12.7 contains more detailed characterization of impulse noise, other quantities that can be measured, and further requirements on instrumentation.

9.5 Spatial aspects

Although this standard is primarily concerned with the measurement of sound-pressure levels at a single point in space, it is often desirable to characterize how the sound pressure level varies over space from one point to another. Generally, such a characterization is simply a matter of taking several individual measurements at different points, each governed by the requirements of this standard. However, this standard does not define requirements on the number or locations of microphone positions, as this will be strongly dependent on the type of spatial characterization being undertaken and its purpose and will usually be defined in another standard or test code being followed.

10 Documentation of measurements—measurement record

All pertinent information, observations, and data should be documented at the time of the measurements. This documentation can take many forms and may ultimately be filed in several different places, but collectively it forms the measurement record for the particular measurement or series of measurements. It serves as the basis for the measurement report. As a minimum, and where applicable, the following information is required or recommended, as indicated. *Système International* (SI) units should be used for all dimensions.

10.1 General information

Required:

(1) Date and place of measurements and names of the responsible personnel.

(2) Citation of all measurement standards or test codes being followed, and description of any deviations

from the prescribed measurement procedures.

Recommended:

(3) Summary of measurement objective, results, and conclusions.

(4) Statement of who authorized the measurements, and why, and any contractual obligations, guarantees, or stipulated agreements between the parties concerned.

10.2 Description of sound of interest

Required:

(1) Description of the sound of interest being measured at the particular point in space (see Sec. 6).

(2) If the sound of interest is associated with an identifiable source or sources, the source(s) should be described in detail, particularly those aspects that affect the acoustical output.

Recommended:

(3) Photographs or drawings of the source(s) or plots of the temporal or spectral characteristics of the sound of interest.

10.3 Description of acoustical environment

Required:

(1) Description of the acoustical environment (see Sec. 7). If indoors, include dimensions, shape, and surface treatment. If outdoors, describe type and topography of terrain and the location of any large reflecting objects.

(2) Locations of any identifiable sound sources and distances from the measurement point.

(3) If outdoors, air temperature, relative humidity, barometric pressure, wind speed, and direction.

Recommended:

(4) If indoors, air temperature, relative humidity, and barometric pressure.

(5) Any other aspects of the physical environment or meteorological conditions believed to affect the acoustical signal at the microphone location.

(6) Photographs or drawings of the physical environment in which measurements are taken.

10.4 Instrumentation

Required:

(1) Identification of the specific instruments used for the measurements, including name, type, serial number, and manufacturer, and type number for sound level meters.

(2) Bandwidth of frequency analyzer(s); order number for fractional-octave-band filters.

(3) Description of the method used for calibration of the instruments (see Sec. 9.2.1 and 9.2.2). Type, serial number, and manufacturer of the calibrator used and date of its last calibration.

(4) Identification of any windscreens or nose cones used with microphones.

Recommended:

(5) Frequency response and dynamic range of instrumentation.

(6) Description of recording equipment and relevant specifications (see Sec. 8.7).

(7) Description of auxiliary equipment or devices used to measure meteorological conditions.

(8) Photographs or block drawings of the instrumentation setup.

10.5 Acoustical data

Required:

(1) Location and orientation of microphone(s).

(2) The measured time-averaged A-weighted sound level or A-weighted sound exposure level, in decibels. If these are computed from more than one individual measurement, state how the computation was performed.

(3) If other quantities are measured or other frequency weightings are employed, these shall be stated.

(4) If a conventional sound level meter is used, the time weighting shall be stated.

(5) The measurement time interval. Details of the sampling procedure used, if any.

(6) Identification of any corrections (in decibels) for microphone frequency response, or for any other reason (state particular section of measurement standard, test code, or other procedure being followed that specifies such a correction).

Recommended:

(7) Remarks on the subjective impressions of the sound of interest, particularly whether or not it contains audible discrete tones (see Annex A) or impulsive sound (see Annex B).

(8) Plots of temporal characteristics (time histories) or spectral characteristics (one-third octave band, FFT spectra, etc.) of the sound of interest at the measurement point.

11 Reporting of measurement results—measurement report

The measurement report is the document or information that is transmitted to parties other than those conducting the measurements. The content, length, and format of the measurement report depends on the purposes of the measurements and the interests of the recipients of the report. As a general rule, it should include only the information that is required or relevant to the purposes at hand. If all the requirements of this standard have been met, the measurement report may state that the reported data have been measured "in full conformance" with this standard. If one, or at most a small number of requirements have not been met, but it is still desired to cite the standard, the measurement report may contain a statement that the procedures of this standard "have been followed, with the following exceptions: … ." The identified exceptions shall be prominently stated; the terms "in full conformance" or "in conformance" shall not be used.

Annex A

(informative)

Identification and evaluation of prominent discrete tones

(Character of the sound)

[This Annex is not part of American National Standard Measurement of Sound Pressure Levels in Air, but is included for information purposes only. The requirements stated in this Annex (e.g., through the use of the word “shall”) are requirements governing the procedures themselves, even though the use of these procedures is optional for this American National Standard.]

A.1 Field of application

When the sound of interest contains an audible discrete tone, it may be desirable to characterize, using an objective measure, the so-called prominence of the tone; that is, how much the tone stands out from the surrounding sound or noise. This Annex describes two procedures for determining tonal prominence: the tone-to-noise ratio method and the prominence ratio method [1-6]. These procedures may be helpful in evaluating the character of the sound, as opposed to the level of the sound.

Discrete tones occurring at any frequency within the one-third octave bands having center frequencies from 100 Hz to 10 000 Hz may be evaluated by the procedures in this Annex (i.e., tones between 89.1 Hz and 11 220 Hz).

National or International Standards or test codes dealing with the measurement of sound pressure levels may refer to this Annex for the determination of the prominence of a tone or tonal component that may be present in the signal measured at a given microphone position. Likewise, other standards or test codes that include guidelines or requirements for the declaration of product noise emissions may refer to this Annex for the identification and evaluation of discrete tones occurring in the noise emissions. For these or similar applications, either the tone-to-noise ratio method or the prominence ratio method may be used, unless otherwise specified in the standards or test codes.

A.2 Background

A discrete tone which occurs together with broadband noise is partially masked by that part of the noise contained in a relatively narrow frequency band, called the critical band, that is centered at the frequency of the tone. Noise at frequencies outside the critical band does not contribute significantly to the masking effect. The width of a critical band is a function of frequency (see A.6). In general, a tone is just audible in the presence of noise when the sound pressure level of the tone is about 4 dB below the sound pressure level of the masking noise contained in the critical band centered around the tone. This is the threshold of audibility. For the purposes of this Annex, a discrete tone is classified as *prominent* when using the tone-to-noise ratio method if the sound pressure level of the tone exceeds the sound pressure level of the masking noise in the critical band by 8 dB for tone frequencies of 1 000 Hz and higher, and by a greater amount for tones at lower frequencies. This corresponds, in general, to a tone being prominent when it is more than 12 dB above the threshold of audibility. When using the prominence ratio method, a tone is classified as prominent if the difference between the level of the critical band centered on the tone and the average level of the adjacent critical bands is equal to or greater than 9 dB for tone frequencies of 1 000 Hz and higher, and by a greater amount for tones at lower frequencies. Reference [6] provides the basis for these values.

A.3 Microphone position

The tone-to-noise ratio or prominence ratio is determined at a particular microphone position, as the prominence of a tone or tonal component may vary from position to position. The actual position used depends on the purpose of the measurement and is usually specified when another standard or test code is being followed. In general, however, the position should be one that is normally occupied by a human listener.

A.4 Instrumentation

A digital Fast Fourier Transform (FFT) analyzer capable of measuring the power spectral density of the microphone signal shall be used for the measurements of this Annex.

The analyzer shall have rms averaging (linear averaging, rather than exponential averaging) capabilities, a Hanning time window function, an upper frequency limit high enough to allow computing the quantities required herein for the particular tone under investigation, and a frequency bandwidth resolution less than one per cent of the frequency of the tone.

The microphone output signal fed to an FFT analyzer shall meet the requirements for type 1 sound level meters stated in ANSI S1.4-1983 and ANSI S1.4A-1985. Because the procedures of this Annex include the option of working directly in terms of sound pressure levels, the FFT analyzer (or, alternatively, the software used for post-processing of the FFT data) should allow calibration directly in terms of sound pressure levels in decibels (reference 20 μPa).

No frequency weighting function (e.g., A-weighting) shall be applied to the analyzer input signal.

The FFT analysis shall use a sufficient number of averages to provide an analysis time consistent with the chosen measurement time interval (see 9.2.7).

A.5 Audibility requirement

Discrete tones should only be classified as prominent if they are, in fact, audible. Therefore, an initial aural examination of the noise emitted from the equipment under test shall be made at the specified microphone position, with the following cases applied.

1. If one or more discrete tones are audible, then the measurement procedures of this Annex for either the tone-to-noise ratio or prominence ratio, or both, shall be carried out for each audible tone. If the criterion for prominence in either A.7.5 or A.8.6 is met for a particular tone, the tone is classified as *prominent.*
2. If no tones are audible, the procedures of this Annex need not be carried out and a statement such as “no audible discrete tones” or “no prominent discrete tones” may be included in the report.
3. If there is doubt as to whether or not audible tones are present (e.g., if the test engineer is not a trained or experienced listener), then other, more objective evidence should be sought. It is recommended that a preliminary FFT or other narrow-band spectrum be taken of the noise. If the spectrum indicates that audible tones may be present (i.e., if it shows one or more sharp spikes), then the following audibility test should be performed for each potential tone. A sinusoidal signal corresponding to the frequency of the tone in question should be generated and listened to, and compared to the noise from the product, noting whether or not a tone at the same frequency is audible in the product noise emissions. If it is not, then the procedures of this Annex need not be carried out for the tone; it is not audible and would not be classified as “prominent.” If the tone is audible, it is treated as in case 1 above.

A.6 Critical bandwidths

The width of the critical band Δf_c, centered at any frequency f_0, can be calculated from the following equation [7]:

$$\Delta f_c = 25.0 + 75.0 \times \left[1.0 + 1.4 \times (f_0 / 1000)^2\right]^{0.69} \tag{A.1}$$

(for example, Δf_c = 162.2 Hz for f_0 = 1 000 Hz and Δf_c = 117.26 Hz for f_0 = 500 Hz).

For the purposes of this Annex, the critical band is modeled as an ideal rectangular filter with center frequency f_0, lower band-edge frequency f_1, and upper band-edge frequency f_2, where

$$f_2 - f_1 = \Delta f_c \ . \tag{A.2}$$

For $f_0 \leq$ 500 Hz, the critical band approximates a constant-bandwidth filter, and the band-edge frequencies are computed as follows:

$$f_1 = f_0 - \Delta f_c / 2 \tag{A.3}$$

and

$$f_2 = f_0 + \Delta f_c / 2 \ . \tag{A.4}$$

For $f_0 >$ 500 Hz, the critical band approximates a constant-percentage bandwidth filter, where

$$f_0 = \sqrt{f_1 \times f_2} \ , \tag{A.5}$$

and the band-edge frequencies are computed from (A.2) and (A.5) as follows:

$$f_1 = -\frac{\Delta f_c}{2} + \frac{\sqrt{(\Delta f_c)^2 + 4 f_0^{\,2}}}{2} \tag{A.6}$$

and

$$f_2 = f_1 + \Delta f_c \ . \tag{A.7}$$

NOTE Although Equation (A.1) for the width of the critical band is well-known and widely used, equations for the corresponding band-edge frequencies have not formally been derived. Given the behavior of the critical band below and above 500 Hz, however, the assignment of the band-edge frequencies according to the above equations seems to be logical. That is, for constant-bandwidth filters, the lower and upper band-edge frequencies are arithmetically related to the center frequency, whereas for constant-percentage bandwidth filters, they are geometrically related.

A.7 Tone-to-noise ratio method

A.7.1 FFT measurement

The operating procedures for the FFT analyzer shall be followed to acquire the power spectral density (or sound pressure level) of the signal at the measurement position, employing the Hanning time window and rms averaging (linear averaging). No frequency weighting, such as A-weighting, shall be applied to the signal fed to the FFT analyzer. The FFT analysis shall use a sufficient number of averages to provide an analysis time consistent with the chosen measurement time interval (see 9.2.7). Zoom analysis should be used with the center frequency of the zoom band corresponding, approximately, to the frequency of the discrete tone, and the width of the zoom band at least equal to, and preferably slightly greater than, the width of the critical band.

NOTE The power spectral density of a signal is usually calculated and displayed as a mean-square value of some quantity per hertz (e.g., a mean-square voltage per hertz (V^2/Hz) or a mean-square sound pressure per hertz (Pa^2/Hz), versus frequency. For the purposes of determining the tone-to-noise ratio, ΔL_T , the units of the measured power spectral density are not important, and absolute calibration of the analyzer to some reference quantity (such as 1 V or 20 μPa) is unnecessary. However, calibration of the instrument in pascals-squared per hertz will enable sound pressure level quantities to be readily obtained. The procedures in this Annex assume this calibration, and the text is written in terms of the "mean-square sound pressure," but to indicate that any quantity may be used, the symbol has been chosen as "X".

A.7.2 Determination of tone level

The mean-square sound pressure of the tone, X_t, (or the tone sound pressure level, L_t) is determined from the FFT spectrum measured above by computing the mean-square sound pressure in the narrow band that "defines" the tone. The width of this frequency band, Δf_t, in hertz, is equal to the number of discrete data points ("lines") included in the band, times the resolution bandwidth ("line spacing"). If the width of the frequency band selected for the purpose of computing X_t is greater than 15% of the width of the critical band centered at the frequency of the tone, the FFT spectrum should be repeated with a smaller resolution bandwidth.

For the determination of the mean-square sound pressure of the tone (or tone sound pressure level) for multiple tones in a single critical band see A.7.6.

NOTE Care should be taken when selecting the bandwidth Δf_t to delineate the discrete tone, especially when automated procedures are being used. If the band is too narrow, the mean-square sound pressure of the tone (or the tone sound pressure level) will be underestimated and the mean-square sound pressure of the noise (see A.7.3) will be overestimated. If the band is too wide, masking noise or secondary tones may be erroneously included with the tone computations and omitted from the noise computation.

A.7.3 Determination of masking noise level

For the purposes of this Annex, the mean-square sound pressure of the masking noise, X_n, (or the masking noise sound pressure level, L_n) is taken as the value determined using the following two-step procedure.

The first step is to compute the total mean-square sound pressure (or the total sound pressure level) in the critical band. The width of the critical band is determined from Equation (A.1) with f_0 set equal to the frequency of the tone under investigation, f_t, and with lower band-edge frequency f_1 and upper band-edge frequency f_2 as given in Equations (A.3) and (A.4) or Equations (A.6) and (A.7).

From the FFT spectrum, the total mean-square sound pressure, X_{tot}, (or the total sound pressure level, L_{tot}) of the critical band is computed. Depending on the particular instrumentation used, this may be performed on the FFT analyzer itself using band cursors, on an external computer using appropriate software, or by some other means. In any event, the width of the frequency band used to compute this value, Δf_{tot}, in hertz, is equal to the number of discrete FFT data points included in the band times the resolution bandwidth.

The second step is to calculate the masking noise mean-square sound pressure, X_n, (or the masking noise sound pressure level, L_n) from the following equation:

$$X_{\mathrm{n}} = (X_{\mathrm{tot}} - X_{\mathrm{t}}) \frac{\Delta f_{\mathrm{c}}}{(\Delta f_{\mathrm{tot}} - \Delta f_{\mathrm{t}})} \tag{A.8A}$$

or

$$L_{\mathrm{n}} = 10\lg\left(10^{0.1L_{\mathrm{tot}}} - 10^{0.1L_{\mathrm{t}}}\right) + 10\lg\left(\frac{\Delta f_{\mathrm{c}}}{\Delta f_{\mathrm{tot}} - \Delta f_{\mathrm{t}}}\right) \text{ dB} \tag{A.8B}$$

For the determination of the mean-square sound pressure of the masking noise (or the noise sound pressure level) for multiple tones in a critical band, see A.7.6.

NOTE The Equation (A.8A) [or Equation (A.8B)] accounts for both the fact that the FFT analyzer bandwidth, Δf_{tot}, used to compute X_{tot} (or L_{tot}) may not be exactly equal to the critical bandwidth, Δf_c, and the fact that the calculated mean-square sound pressure (X_{tot} - X_t), [or the calculated sound pressure level, $10\lg\left(10^{0.1L_{\mathrm{tot}}} - 10^{0.1L_{\mathrm{t}}}\right)$] does not include the noise contained in the narrow band Δf_t.

A.7.4 Determination of the tone-to-noise ratio

The tone-to-noise ratio, in decibels, is calculated as follows:

$$\Delta L_{\mathrm{T}} = 10\lg(X_{\mathrm{t}} / X_{\mathrm{n}}) \text{ dB} \tag{A.9A}$$

or

$$\Delta L_{\mathrm{T}} = L_{\mathrm{t}} - L_{\mathrm{n}} \text{ dB} \tag{A.9B}$$

For the determination of the tone-to-noise ratio for multiple tones in a critical band, see A.7.6.

A.7.5 Prominent discrete tones

A discrete tone is classified as *prominent* according to the tone-to-noise ratio method if

$$\Delta L_{\mathrm{T}} \geq 8.0 \text{ dB}, \qquad \text{for } f_{\mathrm{t}} \geq 1\,000 \text{ Hz}, \tag{A.10A}$$

or

$$\Delta L_{\mathrm{T}} \geq 8.0 + 8.33 \times \lg(1000/f_{\mathrm{t}}) \text{ dB}, \qquad \text{for } f_{\mathrm{t}} < 1\,000 \text{ Hz} \tag{A.10B}$$

and the discrete tone meets the audibility requirement of A.5. The criteria in Equations (A.10A) and (A.10B) are illustrated graphically in Figure A.4.

A.7.6 Multiple tones in a critical band

The noise emitted by a machine may contain multiple tones, and several of these may fall within a single critical band. If one or more tones are audible, the procedure above is followed for each tone, with the following differences. The tone with the highest level in the critical band is identified as the primary tone, and its frequency is denoted as f_p. For the critical band centered on this primary tone, the tone with the second highest level is identified as the secondary tone and its frequency denoted as f_s.

If the secondary tone is sufficiently close in frequency to the primary tone, then the two are considered to be perceived as a single discrete tone and the prominence is determined by combining their mean-square sound pressures (or sound pressure levels). Two tones may be considered sufficiently close or "proximate" if their spacing $\Delta f_{s,p} = \left| f_s - f_p \right|$ is less than the proximity spacing defined as follows [8]:

$$\Delta f_{prox} = 21 \times 10^{1.2 \times \left| \lg(f_p / 212) \right|^{1.8}} \text{ Hz,} \quad \text{for } 89 < f_p < 1000 \text{ Hz} \tag{A.11}$$

(for example, Δf_{prox} = 23 Hz for f_p = 150 Hz; and Δf_{prox} = 64 Hz for f_p = 850 Hz).

If the proximity criterion $\Delta f_{s,p} < \Delta f_{prox}$ is met, then the mean-square sound pressure of the secondary tone, $X_{t,s}$, is added to the mean-square sound pressure of the primary tone, $X_{t,p}$, when calculating the mean-square sound pressure of the tone, X_t, and subtracted from the total mean-square sound pressure, X_{tot}, before calculating the tone-to-noise ratio ΔL_T. (When working with sound pressure levels for this case, the sound pressure level of the secondary tone, $L_{t,s}$, is combined on an energy basis with the sound pressure level of the primary tone, $L_{t,p}$, and subtracted on an energy basis from the total sound pressure level of the noise, L_{tot}). For tone frequencies higher than 1 kHz, the proximity spacing, Δf_{prox} exceeds half the width of the critical band, so the criterion is always met. Thus, in equation form:

$$X_t = (X_{t,p} + X_{t,s}) \tag{A.12A}$$

or

$$L_t = 10 \lg \left[10^{0.1 L_{t,p}} + 10^{0.1 L_{t,s}} \right] \quad , \tag{A.12B}$$

and

$$X_n = \left[X_{tot} - \left(X_{t,p} + X_{t,s} \right) \right] \times \left[\frac{\Delta f_c}{\Delta f_{tot} - (\Delta f_{t,p} + \Delta f_{t,s})} \right] \tag{A.13A}$$

or

$$L_n = 10 \lg \left(10^{0.1 L_{tot}} - (10^{0.1 L_{t,p}} + 10^{0.1 L_{t,s}}) \right) + 10 \lg \left(\frac{\Delta f_c}{\Delta f_{tot} - (\Delta f_{t,p} + \Delta f_{t,s})} \right). \tag{A.13B}$$

With the above values for X_n and X_t, (or L_n and L_t), Equation (A.9) is used to compute the tone-to-noise ratio.

If the proximity criterion is not met, then the tones are considered to be perceived as separate tones and are treated individually. In this case, the mean-square sound pressure of the secondary tone is removed from the mean-square sound pressure of the masking noise (but otherwise ignored; i.e., not added to the mean-square value of the primary tone) before calculating the tone-to-noise ratio of the primary tone. [When working with sound pressure levels for this case, the sound pressure level of the secondary tone is subtracted on an energy basis from the sound pressure level of the noise (but otherwise ignored; i.e., not combined with the sound pressure level of the primary tone) before calculating the tone-to-noise ratio of the primary tone.] In this case, either Equation (A.13A) [or Equation (A13B)] applies directly for X_n (or L_n), but the mean-square sound pressure of the tone is taken solely as $X_t = X_{t,p}$ [or, the tone sound pressure level is taken solely as $L_t = 10\lg\left(10^{0.1 L_{t,p}}\right)$]. With this value for X_t, and with X_n from Equation (A.13A), (or this value of L_t, with L_n from Equation A.13B) Equation (A.9) is used to compute the tone-to-noise ratio for the primary tone.

NOTE When the proximity criterion is not met and it is desired to compute the tone-to-noise ratio for the secondary tone individually, then the above procedure may be repeated with the secondary tone considered as the primary tone. The critical band is then centered on this tone, with all quantities being recomputed.

A.7.7 Complex tones containing harmonic components (tone-to-noise ratio method)

Although laboratory-generated discrete tones may be pure sinusoids, most of the discrete tones that occur in the environment or from the noise emissions from real machinery and equipment are not. As such, the FFT spectrum will generally show a series of tonal components (called harmonics, overtones, or partials) at integral multiples of some fundamental frequency. Usually the fundamental is the strongest component, but this is not always the case. For the purposes of this Annex, each tonal component in the harmonic series which meets the audibility requirement of A.5 shall be evaluated independently.

A.7.8 Example (tone-to-noise ratio method)

A sound pressure level spectrum is shown in Figure A.1. This Figure shows how a single tone in a critical band is analyzed using the tone-to-noise ratio method. Figure A.2 shows how the tone-to-noise ratio method is used when multiple tones exist in a critical band.

A.8 Prominence ratio method

A.8.1 FFT measurement

The operating procedures for the FFT analyzer shall be followed to acquire the power spectral density (or sound pressure level) of the signal at the measurement position, employing the Hanning time window and rms averaging (linear averaging). No frequency weighting, such as A-weighting, shall be applied to the signal fed to the FFT analyzer. The FFT analysis shall use a sufficient number of averages to provide an analysis time consistent with the chosen measurement time interval (see 9.2.7). Zoom analysis should be used with the center frequency of the zoom band corresponding, approximately, to the frequency of the discrete tone, and the width of the zoom band equal to about 4 times the width of the critical band.

NOTE The power spectral density of a signal is usually calculated and displayed as a mean-square value of some quantity per hertz (e.g., a mean-square voltage per Hz (V^2/Hz) or a mean-square sound pressure per hertz (Pa^2/Hz), versus frequency. For the purposes of determining the prominence ratio, ΔL_P, the units of the measured power spectral density are not important, and absolute calibration of the analyzer to some reference quantity (such as 1 V or 20 μPa) is unnecessary. However, calibration of the instrument in pascals-squared per hertz will enable sound pressure level quantities to be readily obtained. The procedures in this Annex assume this calibration and the text is written in terms of the "mean-square sound pressure," but to indicate that any quantity may be used, the symbol has been chosen as "*X*".

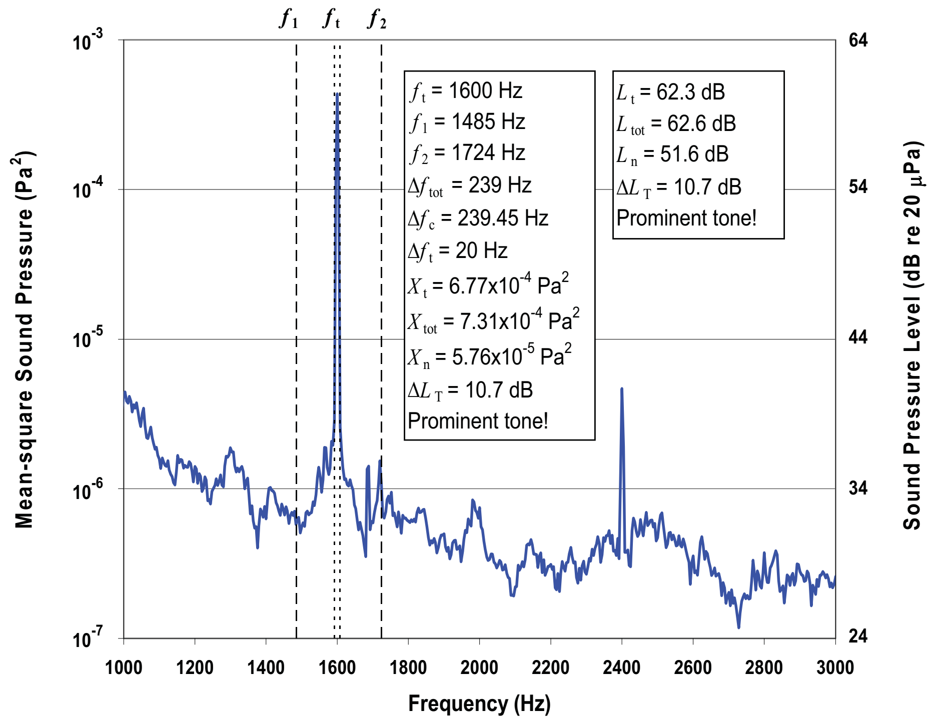

Figure A.1 — Tone-to-noise ratio method applied to a single tone in a critical band

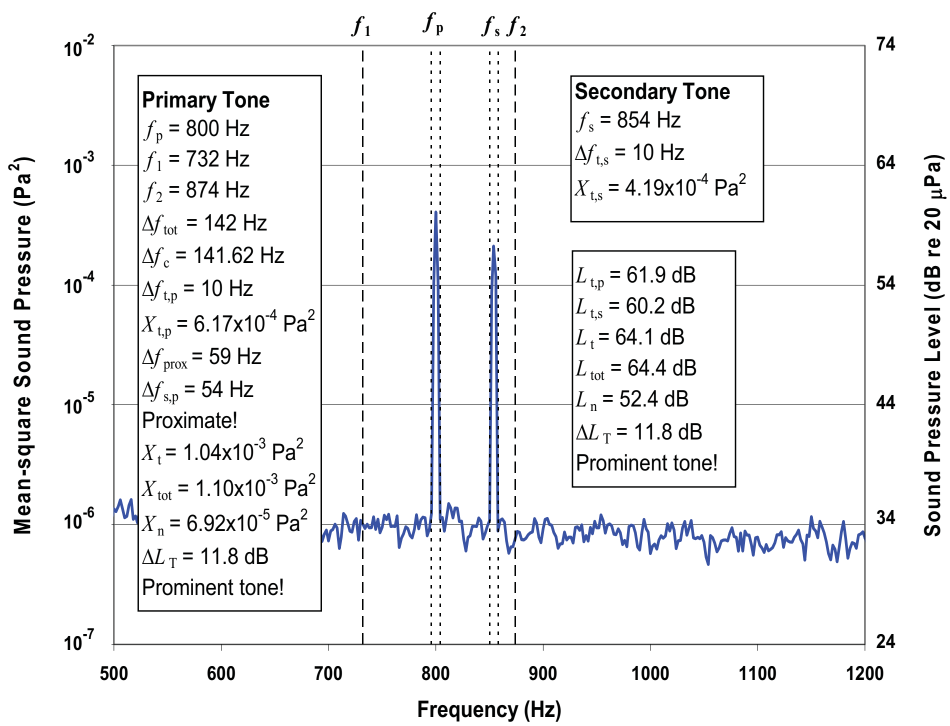

Figure A.2 — Tone-to-noise ratio method applied to multiple tones in a critical band

A.8.2 Determination of the level of the middle critical band

The mean-square sound pressure of the middle critical band, X_M, is defined as the total mean-square sound pressure contained in the critical band centered on the tone under investigation. (When working with sound pressure levels, this quantity becomes the sound pressure level of the middle critical band, L_M.) The width of the middle critical band, Δf_M, as well as the lower and upper band-edge frequencies, $f_{1,M}$ and $f_{2,M}$ are determined from the relationships in A.6 with f_0 set equal to the frequency of the tone under investigation, f_t. The band-edge frequencies then become:

For $f_t \leq$ 500 Hz:

$$f_{1,M} = f_t - \Delta f_M / 2 \tag{A.14}$$

and

$$f_{2,M} = f_t + \Delta f_M / 2 . \tag{A.15}$$

For $f_t >$ 500 Hz:

$$f_{1,M} = -\frac{\Delta f_M}{2} + \frac{\sqrt{(\Delta f_M)^2 + 4 f_t^{\,2}}}{2} \tag{A.16}$$

and

$$f_{2,M} = f_{1,M} + \Delta f_M \tag{A.17}$$

(e.g., $f_{1,M}$ = 922.2 Hz and $f_{2,M}$ = 1084.4 Hz when f_t = 1 000 Hz).

The value of X_M (or L_M) is determined from the FFT spectrum by bracketing the data points lying between $f_{1,M}$ and $f_{2,M}$ and computing the mean-square sound pressure of the middle critical band (or the sound pressure level of the middle critical band). Depending on the particular instrumentation used, this may be performed on the FFT analyzer itself using band cursors, on an external computer using appropriate software, or by some other means.

A.8.3 Determination of the level of the lower critical band

The mean-square sound pressure of the lower critical band, X_L, is defined as the total mean-square sound pressure contained in the critical band immediately below, and contiguous with, the middle critical band defined in A.8.2. (When working with sound pressure levels, this quantity becomes the sound pressure level of the lower critical band, L_L.) The relationships in A.6 govern this lower critical band, with center frequency $f_{0,L}$, bandwidth Δf_L, and lower and upper band-edge frequencies $f_{1,L}$ and $f_{2,L}$, respectively. Since this lower critical band must be contiguous with the middle critical band, it follows that $f_{2,L} = f_{1,M}$. However, because $f_{0,L}$ is not known *a priori*, the equations in A.6 cannot be used directly to determine the value of $f_{1,L}$, and an iterative method of solution would ordinarily have to be used. For the purposes of this Annex, the value of $f_{1,L}$ shall be computed from Equation A.18 (which has been derived from an iterative solution through the use of curve fitting).

$$f_{1,L} = C_0 + C_1 \times f_t + C_2 \times f_t^2 \tag{A.18}$$

where:

Frequency Range (Hz)	C_0	C_1	C_2
$f_t \leq 171.4$	20.0	0.0	0.0
$171.4 < f_t \leq 1600$	-149.5	1.001	-6.90×10^{-5}
$f_t > 1600$	6.8	0.806	-8.20×10^{-6}

For tone frequencies below 171.4 Hz, the lower band-edge frequency for the lower critical band would compute to less than 20 Hz, the accepted lower limit of human hearing. For such cases, the lower band-edge frequency shall be set equal to 20 Hz (so that the band used for the determination of X_L extends from 20 Hz up to $f_{2,L}$). The width of this lower band, Δf_L, will now be less than the width of the true critical band, and the determination of the prominence ratio takes this into account (see A.8.5).

The value of X_L (or L_L) is determined from the FFT spectrum by bracketing the data points lying between $f_{1,L}$ and $f_{2,L}$ and computing the mean-square sound pressure (or the sound pressure level) of the lower critical band. Depending on the particular instrumentation used, this may be performed on the FFT analyzer itself using band cursors, on an external computer using appropriate software, or by some other means. Care should be taken to ensure that the lower critical band and the middle critical band do not overlap computationally; i.e., that the FFT data point(s) closest to the common band edge is (are) assigned uniquely to one band or the other, and not to both.

A.8.4 Determination of the level of the upper critical band

The mean-square sound pressure of the upper critical band, X_U, is defined as the total mean-square sound pressure contained in the critical band immediately above, and contiguous with, the middle critical band defined in A.8.2. (When working with sound pressure levels, this quantity becomes the sound pressure level of the upper critical band, L_U.) The relationships in A.6 govern this upper critical band, with center frequency $f_{0,U}$, bandwidth Δf_U, and lower and upper band-edge frequencies $f_{1,U}$ and $f_{2,U}$, respectively. Since this upper critical band must be contiguous with the middle critical band, it follows that $f_{1,U} = f_{2,M}$. However, because $f_{0,U}$ is not known *a priori*, the equations in A.6 cannot be used directly to determine the value of $f_{2,U}$, and an iterative method of solution would ordinarily have to be used. For the purposes of this annex, the value of $f_{2,U}$ shall be computed from Equation A.19 (which has been derived from an iterative solution through the use of curve fitting).

$$f_{2,U} = D_0 + D_1 \times f_t + D_2 \times f_t^2 \quad \text{(A.19)}$$

where:

Frequency Range (Hz)	D_0	D_1	D_2
$f_t \leq 1600$	149.5	1.035	7.70×10^{-5}
$f_t > 1600$	3.3	1.215	2.16×10^{-5}

The value of X_U (or L_U) is determined from the FFT spectrum by bracketing the data points lying between $f_{1,U}$ and $f_{2,U}$ and computing the mean-square sound pressure (or the sound pressure level) of the upper critical band. Depending on the particular instrumentation used, this may be performed on the FFT analyzer itself using band cursors, on an external computer using appropriate software, or by some other means. Care should be taken to ensure that the upper critical band and the middle critical band do not overlap computationally; i.e., that the FFT data point(s) closest to the common band edge is (are) assigned uniquely to one band or the other, and not to both.

A.8.5 Determination of prominence ratio

The prominence ratio, in decibels, is calculated as follows (for tone frequencies greater than 171.4 Hz):

$$\Delta L_P = 10\lg\left[\frac{X_M}{(X_L + X_U)\times 0.5}\right] \text{ dB ; for } f_t > 171.4 \text{ Hz} . \tag{A.20A}$$

When working with sound pressure levels, the above equation becomes:

$$\Delta L_P = 10\lg\left(10^{0.1L_M}\right) - 10\lg\left[\left(10^{0.1L_L} + 10^{0.1L_U}\right)\times 0.5\right] \text{ dB ; for } f_t > 171.4 \text{ Hz.} \tag{A.20B}$$

For tone frequencies less than or equal to 171.4 Hz, the lower critical band becomes truncated (see A.8.3) so that its width is less than what would be calculated from Equation (A.1). Therefore, for the purposes of computing the prominence ratio for tone frequencies less than or equal to 171.4 Hz, the level in the lower band is normalized to a bandwidth of 100 Hz (the width of a full critical band at these frequencies), so that the above equations are modified as follows.

$$\Delta L_P = 10\lg\left[\frac{X_M}{[X_L \times (100/\Delta f_L)] + X_U)\times 0.5}\right] \text{ dB ; for } f_t \le 171.4 \text{ Hz.} \tag{A.21A}$$

or, when working with sound pressure levels:

$$\Delta L_P = 10\lg\left(10^{0.1L_M}\right) - 10\lg\left[\left([100/\Delta f_L]\times 10^{0.1L_L} + 10^{0.1L_U}\right)\times 0.5\right] \text{ dB ; for } f_t \le 171.4 \text{ Hz.} \tag{A.21B}$$

A.8.6 Prominent discrete tone criterion (prominence ratio method)

A discrete tone is classified as *prominent* according to the prominence ratio method if:

$$\Delta L_P \ge 9.0 \text{ dB,} \qquad \text{for } f_t \ge 1\,000 \text{ Hz} \tag{A.22A}$$

or

$$\Delta L_P \ge 9.0 + 10\times\lg(1000/f_t) \text{ dB,} \qquad \text{for } f_t < 1\,000 \text{ Hz,} \tag{A.22B}$$

and the discrete tone meets the audibility requirement of A.5. The criteria in Equations (A.22A) and (A.22B) are illustrated graphically in Figure A.4.

A.8.7 Complex tones containing harmonic components (prominence ratio method)

Although laboratory-generated discrete tones may be pure sinusoids, most of the discrete tones that occur in the environment or from the noise emissions from real machinery and equipment are not. As such, the FFT spectrum will generally show a series of tonal components (called harmonics, overtones, or partials) at integral multiples of some fundamental frequency. Usually the fundamental is the strongest component, but this is not always the case. For the purposes of this Annex, each tonal component in the harmonic series which meets the audibility requirement of A.5 shall be evaluated independently.

A.8.8 Example (prominence ratio method)

The prominence ratio method is illustrated graphically in Figure A.3. The prominence ratio was calculated according to A.8.5 and was found to be ΔL_P = 12.1 dB for the 1 600 Hz tone. Because the result is more than 9.0 dB, which is the prominence ratio criterion at 1 600 Hz, the tone is classified as *prominent*.

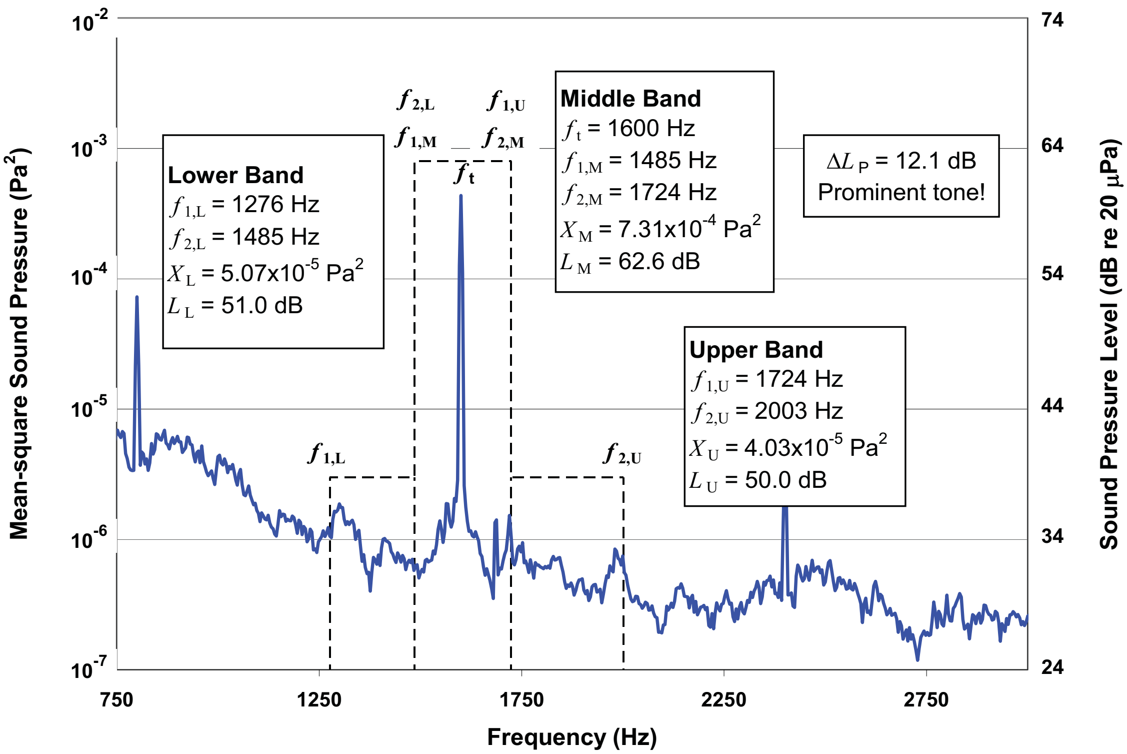

Figure A.3 — Illustration of the prominence ratio method for prominent tone identification

A.9 Information to be recorded for prominent discrete tones

For each discrete tone that has been identified as prominent according to this Annex, the following information shall be recorded:

- The frequency of the tone, f_t, in hertz.
- The method used to evaluate the tone (A.7 tone-to-noise ratio or A.8 prominence ratio).

- If the tone-to-noise ratio method was used, the tone-to-noise ratio, ΔL_T in decibels. If the prominence ratio procedure was used, the prominence ratio ΔL_P in decibels.
- If the noise emissions under investigation include more than one identified prominent tone, the frequency of each tone, and either ΔL_T *or* ΔL_P for each tone.

NOTE It may be useful to additionally record the A-weighted sound pressure level of the prominent tone.

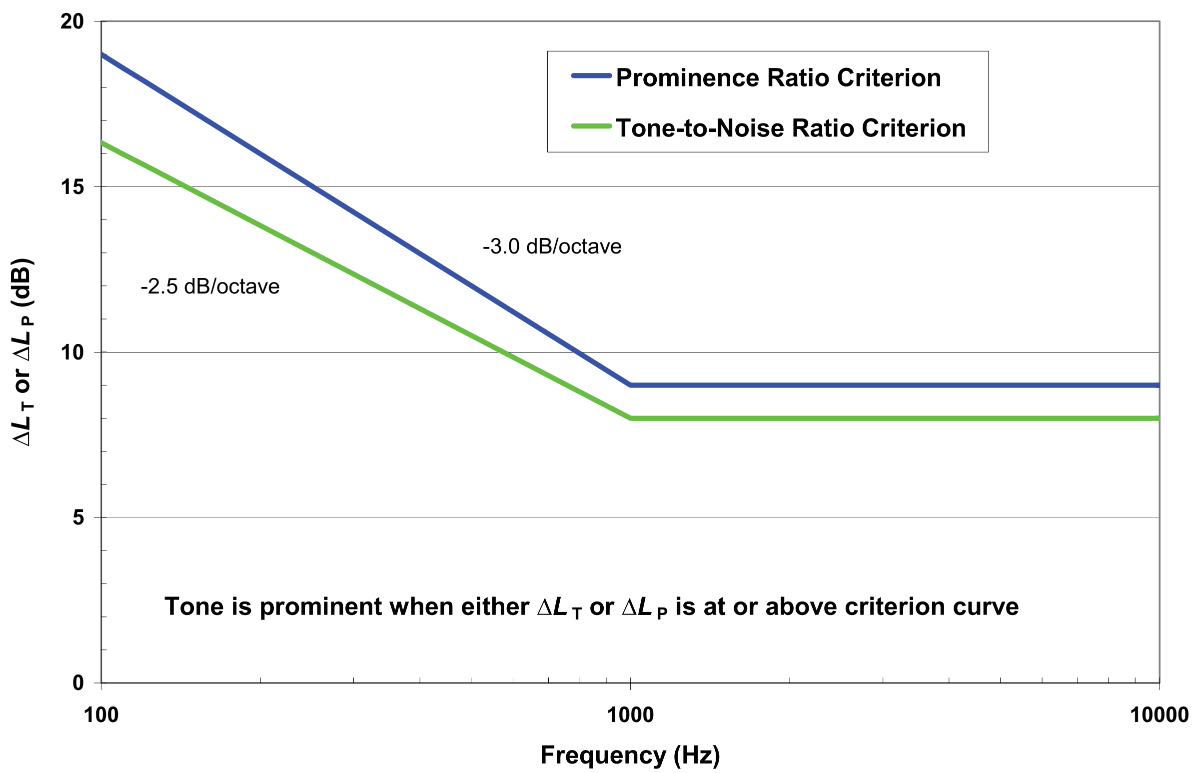

Figure A.4 — Criteria for prominence for both tone-to-noise ratio (A.7.5) and prominence ratio (A.8.6) as a function of frequency

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Annex B

(informative)

Identification and evaluation of impulsive noise

(Character of the sound)

[This annex is not part of American National Standard Measurement of Sound-Pressure Levels in Air, but is included for information purposes only.]

When the sound of interest is impulsive in nature, it is often desirable to characterize, using an objective measure, the degree of impulsiveness. This annex describes a procedure for determining the so-called impulse parameter, ΔL_{I}, which can serve as such an objective measure. The impulse parameter may be helpful in evaluating the character of the sound, as opposed to the level of the sound.

B.1 Definition: Time-averaged AI-weighted sound level

Ten times the common logarithm of the ratio of the time-mean-square AI-weighted sound pressure during a stated time interval to the square of the reference sound pressure. Unit: decibel (dB); symbol: $L_{\mathrm{AI},T}$. The time period of the integration (averaging time), $T = t_2–t_1$, must be specified.

The time-averaged AI-weighted sound level is given by the formula

$$L_{\mathrm{AI},T} = 10 \log_{10}\left[\left(\frac{1}{T}\int_{t_1}^{t_2} p_{AI}^2(t)dt\right)/\, p_0^2\right] \text{ dB},$$

where

$L_{\mathrm{AI},T}$ is the time-averaged AI-weighted sound level, meaning the time-averaged sound pressure level using A-frequency weighting and I-time weighting, determined over a time interval $T=(t_2–t_1)$,

$p_{\mathrm{AI}}^2(t)$ is the squared AI-weighted sound pressure, meaning the squared sound pressure, A-frequency weighted and I-time weighted.

B.2 Measurement position

The impulse parameter is determined at a particular microphone position, as the impulsiveness of the sound may vary from position to position. The actual position used depends on the purpose of the measurement and is usually specified when another standard or test code is being followed. In general, however, the position should be one that is normally occupied by a human listener.

B.3 Instrumentation

An integrating–averaging sound level meter equipped with the I-time weighting and meeting the requirements of Appendix B of ANSI S1.43 is used for the measurements. If the sound of interest is such that a conventional sound level meter may be used (see Sec. 9.4), the sound level meter may also be used to determine the impulse parameter, in which case it should be equipped with the I time weighting and meet the requirements for a type 1 sound level meter specified in ANSI S1.4.

B.4 Measurements

At the measurement position, both the time-averaged AI-weighted sound level $L_{\mathrm{AI},T}$, and the time-averaged A-weighted sound level $L_{\mathrm{A},T}$ are measured (averaged over equal time intervals). If the instrumentation permits, these should both be measured simultaneously. The difference in decibels between these two quantities is defined as the impulse parameter; namely, $\Delta L_{\mathrm{I}} = L_{\mathrm{AI},T} - L_{\mathrm{A},T}$ dB. Generally, the higher the value of the impulse parameter, the more impulsive the sound is perceived to be. If $\Delta L_{\mathrm{I}} \geq 3$ dB, the sound may be classified as *impulsive.*

The time-averaged AI-weighted sound level should only be used to determine whether or not the sound is impulsive or to rate the degree of impulsiveness. It should not be used as a substitute for the time-averaged A-weighted sound level or reported as a sound level measurement, even for sounds that are determined to be impulsive.

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