F-31-09

ANSI S1.13-1971

American National Standard

methods for the measurement of sound pressure levels

american national standards institute, inc.
1430 broadway, new york, new york 10018

3054

ANSI
S1.13-1971

Partial Revision
of S1 2-1962 (R1971)

American National Standard Methods for the Measurement of Sound Pressure Levels

Secretariat

Acoustical Society of America

Approved July 14, 1971

American National Standards Institute, Inc

American National Standard

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Published by

American National Standards Institute
1430 Broadway, New York, New York 10018

Printed in the United States of America

A15C1070/5

Foreword

(This Foreword is not a part of American National Standard Methods for the Measurement of Sound Pressure Levels, S1.13-1971.)

This standard comprises a part of a group of definitions, standards, and specifications for use in acoustical work. It has been developed under the Standards Committee method of procedure, under the sponsorship of the Acoustical Society of America.

American National Standards Committee S1, under whose jurisdiction this standard was developed, has the following scope:

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

Various subcommittees have been organized to take care of the committee's program, and this standard was developed by Working Group S1-51.

This standard is a revision of Section 2 of American National Standard Method for the Physical Measurement of Sound, S1.2-1962 (R 1971).

Suggestions for improvement gained in the use of this standard will be welcome. They should be sent to the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

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American National Standard Methods for the Measurement of Sound Pressure Levels

Introduction

(The material in this Introduction is intended for purposes of background and orientation.)

This standard is concerned with the measurement of sound pressure levels in air under a variety of conditions. The sound to be measured is frequently undesired (that is, noise). The basic purpose of this standard is to establish uniform procedures for obtaining sound pressure level data.

Sound pressure levels to be measured fall into two broad categories: those that are due to a specific source and those that characterize an ambient environment where the sound is usually generated by many sources. It is not always possible to make a clear distinction between these two categories. For example, the ambient noise in a community is often generated by many different sources, but primary concern may be focused on one particular source. In neighborhood A, the noise generated by the source may be masked by the ambient noise, while in neighborhood B, it may be audible. The ambient noise thus is important as a reference level for the evaluation of the noise from a particular source.

Even if the ambient noise has a low level, the measurement of sound pressure level does not always suffice for the quantitative evaluation of a source because the magnitude of the sound pressure level will depend upon the distance from the source, the directivity of the source, and the acoustic environment. For this reason, the total acoustic power radiated by a source of sound may provide a better measure of source output. Since acoustic power is usually calculated from measured values of sound pressure which depend on the acoustic environment, it is necessary to design and calibrate the measurement environment carefully if the accuracy required for sound ratings and comparisons is to be achieved. All aspects of the determination of sound power of sources are covered by other American National Standards. This standard specifically excludes those sound pressure level measurements which are obtained in order to permit calculation of the sound power radiated by a source.

Primary interest in this standard is focused on sound pressure level data which are obtained for their own sake. Since the human ear is a pressure-sensitive device, sound pressure level [illegible] are frequently sufficient to satisfy the purposes of the measurements.

This standard deals exclusively with objective methods of measurement. In many situations, it is desirable to make quantitative assessments of the subjective effects of noise on human beings. The measurements described here yield the physical data that are required for assessing the effects of noise but the assessment techniques themselves (for example, methods for calculating loudness, noise ratings with respect to the conservation of hearing, speech interference and noisiness, predictions of structural failure) are not included.

This standard describes three methods that can be used for measuring sound pressure levels (see Table 1). One method uses a relatively simple, portable instrument; the other two methods require more extensive instrumentation, but yield more detailed information. The choice of the method to be used for a specific measurement program will depend on the objectives of the program.

The techniques for measuring airborne sound pressure levels are summarized in Fig. 1. In planning a series of sound pressure measurements, it is imperative that the purpose of the measurements be kept clearly in mind. In Fig. 1, the purposes of a program of sound pressure level measurements are shown to be either for characterizing a sound source or an ambient sound field. In either case, if the objective is to obtain data on which engineering changes to the source (or sound field) are to be based, band pressure levels are required. On the other hand, if the purpose of the measurements is to obtain a quantity that relates the magnitude of the sound stimulus to an estimate of the effect of the noise on man, a simpler measurement (such as a weighted sound pressure level) may be all that is necessary.

The three different methods for sound pressure level measurements described in this standard are summarized in Table 1. The method to be selected depends upon the thoroughness of the description required for the purposes of the measurements. A thorough description requires an analysis of the sound pressure levels in narrow frequency bands from measurements made at suitable microphone locations over an appropriate time interval with the best available instrumentation. In other situations, a simplified measuring procedure may be entirely adequate for the purposes of the measurements.

The *survey method* that utilizes a hand-held sound-level meter is the least time-consuming but provides comparatively little information, that is, the weighted sound pressure level. No effort is made to control the acoustic environment; that is, the environment is in an "as is" condition, indoors or outdoors.

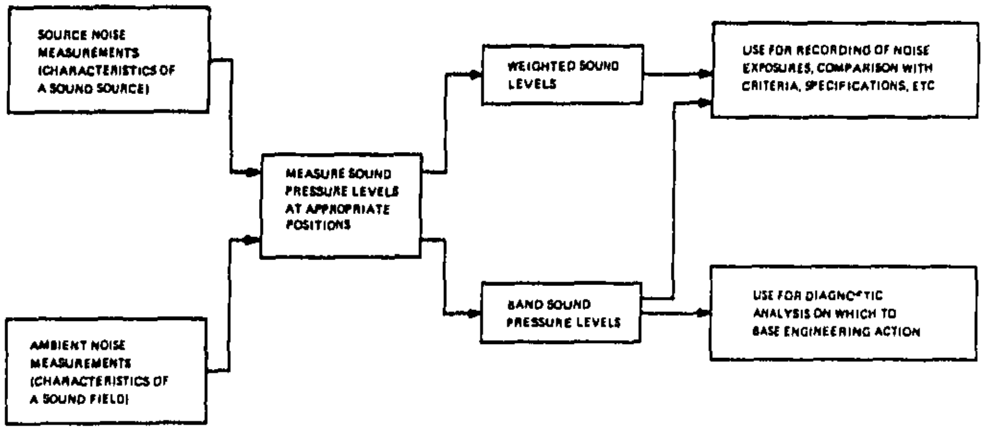
The *field method* utilizes equipment for frequency-band analysis and the acoustic environment may be modified to make it approach known conditions of measurement, or it may be in an "as is" condition either indoors or outdoors. For example, if measurements on a single machine are to be made in a machine shop, the environment may be left "as is" in a reverberant condition so that the room has an effect on the sound pressure levels at the various microphone positions. Alternatively, the environment may be controlled to a degree by covering some of the room surfaces with sound absorptive materials. The effect of the room on the sound pressure level measurements may then be reduced.

The *laboratory method* requires the use of the best

Table 1
Three Methods for Sound Pressure Measurements Described in This Standard

Measurement Method	Instrumentation	Environment	Location
Survey	Sound-level meter	"As is"; not controlled	Indoors or outdoors
Field	Instruments that meet requirements of applicable American National Standards	"As is" or semi-controlled with minor changes to add absorptive materials, remove reflecting objects, etc	Indoors or outdoors
Laboratory	Laboratory instruments that meet requirements of American National Standards	Controlled environment: anechoic or semi-anechoic room	Laboratory (indoors)

Fig. 1
Classification of Airborne Noise Measurements According to Purpose



available, laboratory-grade instrumentation. The frequency-band analysis is carried out under carefully controlled environmental conditions in a laboratory so that the effect of the room on the sound pressure level measurements may be precisely determined. The laboratory method is primarily used for source measurements.

The two types of noise encountered in practice are given below:

(1) Steady Noise
  Without audible discrete tones
  With audible discrete tones
(2) Nonsteady Noise
  Fluctuating noise
  Intermittent noise
  Impulsive noise
    Isolated bursts
    Quasi-steady noise

Steady noise is relatively constant over a long period of time and may or may not contain audible discrete tones. If none of the frequencies is audibly distinguishable from the others, the noise is wide-band and "unpitched." Nonsteady noise may be either fluctuating (that is, does not remain at any constant level during the period of observation), intermittent (that is, returns to the ambient level during the period of observation) or impulsive. These different types of noise require different measurement techniques which are described in detail in this standard.

The particular method selected for measuring noise thus depends upon:

(1) The nature and location of the noise source(s)
(2) The use to be made of the results of the measurements
(3) The type of noise to be measured
(4) The time and equipment available for the measurements, and
(5) The skill of the individual conducting the measurements

Before making a decision on measurement method and instrumentation system, the individual who intends to carry out a program of sound pressure level measurements should ask himself the following general questions:

(1) What do I want to know?
(2) What will I do with the data obtained?
(3) How accurate do I expect the data to be?

The answers to these questions and consideration of the five preceding items should provide guidance on the method to be chosen for the measurements and the instrumentation system to be selected.

This standard classifies the purposes of the measurements, identifies different kinds of commonly encountered noises, describes techniques for measuring and reporting steady and nonsteady noises as well as the instrumentation systems suitable for such measurements, and includes general guidelines for noise measurements in the field and in the laboratory.

1. Scope and Purpose

1.1 Scope

1.1.1 General recommendations are given to assist in the development of noise measurement techniques that are satisfactory for use under various environmental conditions.

1.1.2 The measurement of sound produced by sources which radiate directly into the air is given first priority. The airborne sound pressures may be partially attributable to sound transmission along structural pathways and reradiation from solid (or fluid) bodies.

1.1.3 Primary consideration is given to the measurement of sound created as a by-product of the principle function of the source. The methods may also be applied to other sources which are intended to generate sound. For example, measurements may be desired of the sound pressure generated by an alarm device operating in the presence of multiple noise sources.

1.1.4 This standard does not consider sound pressure level measurements which are obtained for the purpose of determining the sound power radiated by a source.

1.2 Purpose. The purpose of this standard is to provide uniform guidelines for measuring and reporting sound pressure levels observed under different environmental conditions. This standard is applicable to the many different types of sound pressure level measurements commonly encountered in practice. This standard is intended to assist in the preparation of test codes for: 1) determining compliance with a specification, ordinance, or acoustical criterion, and 2) obtaining information to assess the effects of noise on people or equipment.

2. Definitions

ambient noise. The all-encompassing noise associated with a given environment, being usually a composite of sounds from many sources near and far.

discrete tone. A sound wave whose instantaneous sound pressure varies essentially as a simple sinusoidal function of time.

fluctuating noise. A noise whose sound pressure level varies significantly but does not equal the ambient environmental level more than once during the period of observation.

impulsive noise. A noise characterized by brief excursions of sound pressure (acoustic impulses) which significantly exceed the ambient noise. The duration of a single impulse is usually less than one second.

intermittent noise. A noise whose sound pressure level equals the ambient environmental level two or more times during the period of observation. The period of time during which the level of the noise remains at an essentially constant value different from that of the ambient is on the order of one second or more.

nonsteady noise. A noise whose sound pressure level shifts significantly during the period of observation.

period of observation. The time interval during which acoustical data are obtained. The period of observation is determined by the characteristics of the noise being measured and should be at least ten times as long as the response time of the instrumentation. The greater the variation in indicated sound level, the longer must be the observation time for a given expected precision of the measurement.

sound level (noise level). Weighted sound pressure level obtained by the use of a metering characteristic and the weightings A, B, C (or other) as specified in the referenced standards (see Section 12). The weighting employed must be indicated. Unit: decibel (dB).

sound pressure level. Twenty times the logarithm to the base 10 of the ratio of the pressure of a sound to the reference sound pressure. Unless otherwise specified, the effective (rms) pressure is to be understood. The reference sound pressure is 20 $\mu N/m^2$. Unit: decibel (dB).

steady noise. A noise whose sound pressure level remains essentially constant (that is, fluctuations are negligibly small) during the period of observation.

3. Acoustic Environments

3.1 General. The sound pressure observed in the vicinity of the source may be influenced by the acoustic environment in which the source is operating. Small changes in orientation of the source may result in appreciable changes in the sound pressure level. It is imperative that the influence of the environment on the measurement of sound pressure level be considered.

3.2 Types of Measurements

3.2.1 Ambient Noise Measurements. Measurements of ambient noise are commonly made both outdoors and indoors. The observed sound pressure is usually a superposition of the sound pressures generated by many sources at different locations. In this type of measurement, it is the total sound pressure that is of interest rather than the sound pressure generated by any of the individual sources operating in the environment. A statistical description of the combined noise level produced by all of the sources operating simultaneously is frequently of interest. Typical ambient environments are given in Table 2.

3.2.2 Source Measurements. This type of measurement involves the determination of the sound pressure level produced by a source, located either outdoors or indoors. The source of interest will frequently be operating in the presence of other sources. The other sources establish the ambient noise. Typical sources are also listed in Table 2.

3.2.3 Example. The noise levels of a large city are frequently controlled by vehicular traffic (ambient environmental noise). If interest is focused on individual vehicles in the traffic, source measurements are necessary.

3.3 Environmental Factors Influencing Ambient Noise Measurements

3.3.1 Ooutdoors. The sound pressure levels measured outdoors will be influenced by:

(1) Sound absorption by the surface of the ground

Table 2
Typical Ambient Environments and Sources

Ambient Environment	Source
Outdoors	
Highway	Pneumatic tools
Residential neighbourhood	Industrial machines
Airport	Stationary engines
	Equipment used by utilities: transformers, regulators, etc
	Ground vehicles
	Aircraft
	Boats and ships
Indoors	
Factories	Hand tools
Offices	Appliances
Schools	Industrial machines
Hospitals	Household equipment
Dwellings	

(2) Shape of the land contours

(3) Scattering from and absorption by objects such as buildings, trees, and people

(4) Inhomogeneities in the atmosphere (turbulence, wind gradients, and temperature gradients)

(5) Air absorption (ambient temperature and humidity)

(6) Time of day

3.3.2 **Indoors.** The sound pressure levels measured inside buildings will be influenced by:

(1) Sound reflection and absorption by the interior surfaces

(2) Reflections from and absorption by objects within the building, such as furniture and people

(3) External noise sources and the transmission characteristics of the structure

(4) Air absorption (ambient temperature and humidity)

3.4 Environmental Factors Influencing Source Measurements

3.4.1 **General.** Accurate measurements of sources are complicated because the pattern of sound radiation depends upon several environmental factors.

3.4.1.1 **Radiation in a Free Field.** At large distances from a source in a reflection-free, homogeneous, nondissipative space, the sound pressure varies inversely with the distance from the source; that is, the sound pressure level will decrease six decibels each time the distance from the acoustic center of the source is doubled. If the source is large compared with the wavelength of the sound it radiates, the general trend of pressure will be to decrease as the distance from the source is increased, but sound pressure maxima and minima may occur in the vicinity of the source.

3.4.1.2 **Effect of a Reflecting Plane.** When the sound source is located near a reflecting plane, sound waves reflected from the plane will interfere with those coming directly from the source. The general trend of the pressure will be to decrease as the distance from the source is increased and sound pressure maxima and minima will occur due to interference.

3.4.1.3 **Radiation Within a Room.** When a sound source radiates into a room, the sound will be reflected back and forth many times from the room surfaces; these reflections create complicated sound field. At any point within the room, the sound pressure may be considered to be the resultant of two coincident sound fields: the direct sound field which comes directly from the source without being first reflected, and the reverberant sound field. The reverberant sound field is itself the superposition of many sound waves which may interfere to produce spatial and temporal variations in sound pressure.

3.4.2 **Optimal Conditions Outdoors.** To realize optimal conditions outdoors for sound pressure measurements above a reflecting plane, the following requirements shall be met:

3.4.2.1 **Extent of Reflecting Plane.** A hard, smooth, massive plane surface shall extend from the source under test at least a distance $\lambda/2$ beyond the farthest microphone position, where λ is the wavelength of the sound at the lowest frequency of interest.

3.4.2.2 **Absorption Coefficient of Reflecting Plane.** The normal-incidence sound absorption coefficient of the reflecting plane shall not exceed 0.1 over the frequency range of interest (concrete or asphalt surfaces usually meet this requirement).

3.4.2.3 **Obstacles and Reflecting Surfaces.** No obstacles or reflecting surfaces with major dimensions greater than $\lambda/4$ (other than the ground) shall be within 5λ of the source, or within 5λ or $5r$ of the microphone positions, whichever is the greater, where λ is the wavelength of sound at the lowest frequency of interest and r is the distance from the farthest measurement position to the center of the source.

3.4.2.4 **Atmospheric Conditions.** The atmosphere shall be homogeneous to a height of 10 m above the ground or to the height of the source, whichever is greater, with a uniform negative temperature gradient and with no wind gradients. If measurements must be made under conditions with positive temperature gradients (thermal inversions), the positive temperature gradient shall not exceed 2°C per 300 m of height and the wind gradient shall not exceed 3 m/s per 300 m of height. Measurements shall not be made when the wind speed exceeds 6 m/s.

3.4.3 **Optimal Conditions Indoors.** Optimal conditions exist indoors in a free-field or anechoic room. Within the frequency range of interest, the sound waves reflected from the surfaces of the room make a negligible contribution (that is, less than 0.2 dB) to the sound pressure level at the point of observation. To realize free-field conditions in an enclosure, the test room shall meet the following requirements:

3.4.3.1 **Size of Test Room.** The dimensions of the anechoic room shall be large enough so that the microphones can be placed in the far radiation field of the sound source under test and at least $\lambda/4$ distant from the absorptive surfaces of the anechoic room, where λ is the wavelength of sound at the lowest frequency of interest.

NOTE: A useful rule of thumb is that the far radiation field exists un   optimal conditions at distances greater than four times the largest source dimension. This does not imply that distances less than four times the largest source dimension are necessarily in the near field.

3.4.3.2 Absorption Coefficient of Test Room. The average normal-incidence sound absorption coefficient of all surfaces of the anechoic room should be equal to or greater than 0.99 over the frequency range of interest. The absorptive treatment shall be uniformly distributed over all of the surfaces. Most anechoic rooms with absorptive wedges at least 1 m long meet this criterion at frequencies above 100 Hz.

3.4.3.3 Obstacles and Reflecting Surfaces. Sound reflecting surfaces and obstructions other than the microphone and those associated with the sound source under test shall be absent from the room.

3.4.3.4 Free Field Above a Reflecting Plane. A semi-anechoic room with a free field over a reflecting plane shall incorporate all of the features described in 3.4.3.1, 3.4.3.2, and 3.4.3.3 except that the floor is a hard, smooth, massive plane surface. The average normal-incidence sound absorption coefficient of the floor shall not exceed 0.1 over the frequency range of interest. A concrete floor meets this requirement.

3.4.4 Other Indoor Environments. For many sources, it is either desirable or necessary to make measurements under conditions which are not optimal. For example, an indoor environment may have only a small amount of sound absorption. It may be desirable to leave the environment as it is while determining the sound levels in the environment when a particular source is in operation. Or, alternatively, it may be desirable to make the environment more closely approximate the optimal conditions described in 3.4.3 by introducing absorptive treatment.

3.4.4.1 Requirements. When conditions indoors are not optimal, useful measurements can be made without excessive errors due to sound reflections from walls or other surfaces provided that:

(1) The room has an adequate volume

(2) The source is located sufficiently far from the walls and other reflecting surfaces

(3) The measurement positions are relatively close to the source (see 7.3.2.1)

(4) Local interference patterns are smoothed out (see 8.3.1)

3.4.4.2 Qualification Procedures. Section 10 gives procedures for qualifying indoor environments as far as requirements (1) and (2) of 3.4.4.1 are concerned.

3.4.4.3 Nearby Objects

3.4.4.3.1 Survey Method. The acoustic environment in which the measurements are made shall be taken in an "as is" condition.

3.4.4.3.2 Field Method. To the extent possible, it is usually desirable while acoustical measurements are being made to remove all objects from the test area which are not part of the source or necessary for its operation.

3.4.4.3.3 Laboratory Method. All objects which are not part of the source or necessary for its operation shall be removed from the anechoic or semi-anechoic room during the measurements, except for the microphone and its associated hardware.

4. Classification of Noise by Type

4.1 General. The spectrum of a noise is influenced by a number of factors, such as the characteristics of the source(s), environmental conditions, etc. The spectrum may contain components at one or more discrete frequencies whose amplitudes are substantially higher than those of components at adjacent frequencies.

4.2 Types of Noise. The noises usually encountered in practice are classified as steady or nonsteady noise.

4.2.1 Steady Noise. The level of a steady noise remains essentially constant (that is, fluctuations are negligibly small) during the period of observation. To the typical observer, a change in noise level of less than one decibel is not likely to be detectable while a six decibel change will be considered significant. If the average noise level is relatively constant but the spectral distribution of the sound changes during the period of observation (as determined by listening), the noise shall be classified as nonsteady.

4.2.1.1 Steady Noise Without Audible Discrete Tones. This type of noise is frequently referred to as "broad-band" noise; prominent discrete components and narrow-bands of noise are absent. The plot of pressure spectrum level versus frequency is without pronounced discontinuities. See Appendix A for procedures to identify prominent discrete tones in the presense of broad-band noise.

4.2.1.2 Steady Noise with Audible Discrete Tones. This type of noise has components at one or more discrete frequencies which have significantly greater amplitudes than those of the adjacent spectrum (see Appendix A). Clusters of such components or narrow-bands of noise may be observed. The plotted spectrum obtained with a narrow-band analyzer has very sharp peaks (prominent single-frequency components) or steep gradients (narrow bands of noise). The distinguishing feature of narrow-band noise is that its energy is concentrated in a relatively narrow portion of the spectrum.

4.2.2 Nonsteady Noise. The level of a nonsteady noise shifts significantly during the period of observation. This type of noise may or may not contain audible discrete tones. The classification of nonsteady noises depends upon the period of observation which must be defined for each measurement.

4.2.2.1 Fluctuating Noise. The sound pressure level varies over a range greater than six decibels with the "slow" meter characteristic (see 8.1) and does not equal the ambient level more than once during the period of observation. Alternatively, the noise may fluctuate between two or more steady levels six or more decibels apart when measured with the "fast" meter characteristic of a sound-level meter. Fluctuations may occur because of beats between two or more audible discrete tones having nearly the same frequency.

4.2.2.2 Intermittent Noise. The sound pressure level equals the ambient level two or more times during the period of observation. The period of time during which the level of the noise remains at an essentially constant value different from that of the ambient is of the order of one second or more.

4.2.2.3 Impulsive Noise (Bursts). Impulsive noise is characterized by brief excursions of sound pressure (acoustic impulses) which significantly exceed the ambient environmental sound pressure. The duration of a single impulse is usually less than one second. Two subcategories of impulsive noise are:

4.2.2.3.1 Isolated Bursts. One or more bursts occur during the period of observation. The envelope of the burst waveform may be that of a decaying transient or it may be of essentially constant amplitude, for example, a tone burst. The burst spacing (time interval between bursts) is such that each burst is individually distinguishable with a sound-level meter.

4.2.2.3.2 Quasi-Steady Noise. A train of two or more bursts occur during the period of observation. Individual bursts in the train may have equal or unequal amplitudes and the burst spacing (time interval between bursts) may be uniform or nonuniform. As the burst repetition rate increases, the resolution of individual bursts by a sound-level meter becomes difficult; the noise is then classified as quasi-steady.

4.3 Examples. Examples of sources of different types of noise are given in Table 3.

5. Instrumentation for Noise Measurements

5.1 Introduction. Noise measurements are often made with a sound-level meter. When one of the built-in weighting networks is used to modify the frequency response of the instrument, the reading of the meter is called the sound level and the weighting network used must be indicated. When no weighting is used, all frequency components in the range of the

Table 3
Examples of Sources of Different Types of Noise

Steady	Nonsteady
Without Audible discrete tones	Fluctuating
Distant city	Heavy traffic (nearby)
Waterfall	Pounding surf
Air-conditioning system (high velocity)	Intermittent
With audible discrete tones	Aircraft fly-over
Circular saw	Automobile passing by
Transformer	Train passing by
Turbojet engine	Impulsive
	Isolated bursts
	Drop forge hammer
	Dog barking
	Pistol shots
	Door slamming
	Electrical circuit breaker
	Quasi-steady noise
	Riveting
	Pneumatic hammer
	Machine gun

instrument are passed essentially without attenuation and the reading of the meter is the sound pressure level.

The sound level (weighted sound pressure level) is useful in many situations. It is particularly valuable when noises are to be compared which have the same general character and when the human ear does not readily recognize an important qualitative differences in the composition of the noises. When the sound-level meter indicates approximately the same sound level for two noises, but the ear distinguishes differences in the composition of the noises, a single number, such as the one a sound-level meter provides, may be misleading.

The single number provided by the sound-level meter is not sufficient for diagnostic purposes. For studies that are concerned with the causes of noise generation and methods for reducing the noise, a frequency analysis of the noise is required. To obtain this information, band-pass filters whose geometric mean frequency is either continuously or step-wise variable are used in conjunction with the sound-level meter. The sound pressure level, in frequency bands of known width, is then obtained. Eight octave-band filters (for example, those with geometric mean frequencies of 63, 125, 250, 500, 1000, 2000, 4000 and 8000 Hz) usually cover the significant portions of the audible spectrum and provide adequate information to characterize steady noise without audible discrete tones. When audible discrete tones are present in the spectrum, a spectrum analyzer having a narrow bandwidth (for example, third-octave or narrower) may be required.

5.2 General. Instrumentation for the three methods of noise measurement is described in this section.

5.2.1 Survey Method (for Ambient Noise and Source Measurements). This method uses only a sound-level meter to yield the weighted sound pressure level (sound level).

5.2.2 Field Method (for Ambient Noise and Source Measurements). This method uses octave or narrower band analyzers and provides a frequency analysis of the noise in a field environment which may or may not be changed to approximate optimal conditions.

5.2.3 Laboratory Method (Primarily for Source Measurements). This method uses precision octave or narrower band analyzers and provides a frequency analysis of the sound pressure levels produced by a source operating in a free field or a free field above a reflecting plane.

5.3 Instrumentation

5.3.1 Survey Method. For survey measurements, a sound-level meter shall be used whose performance meets or exceeds the least stringent requirements of American National Standard for Sound Level Meters, S1.4-1971 (see Section 12).

5.3.2 Field Method. For field measurements, an octave-band analyzer or a narrow-band analyzer of the constant bandwidth or constant percentage bandwidth type shall be used. The microphone shall be detachable from the instrumentation for installation at the end of a cable.

NOTE: If an analyzer with filt that meet the requirements of Z24.10-1953 (superseded) is us reference should be made to American National Standard Specification for Octave, Half-Octave, and Third-Octave Band Filter Sets, S1.11-1966, on filters for a method to convert the sound pressure level data to the corresponding values for an analyzer that incorporates the current preferred octave-band center frequencies (see Section 12).

5.3.3 Laboratory Method. For laboratory measurements, instrumentation that meets the requirements of 5.3.2 shall be used. In addition, the microphone shall meet the stability, temperature coefficient, and ambient-pressure coefficient requirements of American National Standard Specifications for Laboratory Standard Microphones, S1.12-1967 (see Section 12).

5.4 Precision Objectives of Basic Instrumentation Systems

5.4.1 Precision of Calibration. These systems shall be such that they are capable of being calibrated at a discrete frequency between 200 Hz and 1250 Hz with the following precisions (see 5.7):

(1) Instrumentation for survey method: ±2 dB

(2) Instrumentation for field method: ±1 dB

(3) Instrumentation for laboratory method: ±0.5 dB

A complete calibration over the entire frequency range of interest shall be performed periodically with a precision sufficient to ensure compliance with the frequency response requirements of 5.4.2. Calibrations shall be performed in accordance with the general principles of American National Standard S1.4-1971.

5.4.2 Frequency Response. The frequency response of an instrumentation system to a plane progressive sinusoidal sound wave arriving at the angle of incidence specified by the manufacturer or to sounds arriving at random incidence shall conform to the requirements of American National Standard S1.4-1971. Instrumentation for the laboratory method shall satisfy or exceed the frequency response requirements of the type of sound-level meter which has the most stringent performance specifications. For the field method, instrumentation shall satisfy or exceed the frequency response requirements of the next most stringent sound-level meter specifications and for the survey method, the least.

5.4.3 **Microphone Characteristics.** Microphone characteristics shall conform to the requirements of American National Standard S1.4-1971. Microphones for the laboratory method shall satisfy or exceed the appropriate requirements of the type of sound-level meter with the most stringent performance specifications and, in addition, shall satisfy the stability, temperature coefficient, and ambient-pressure coefficient requirements of American National Standard S1.4-1971. For the field method, microphones shall satisfy or exceed the next most stringent sound-level meter specifications and for the survey method, the least.

5.4.4 **Filter Characteristics.** The octave and third-octave band filter sets used for measurements by the field and laboratory methods shall meet the requirements of American National Standard S1.11-1966. In particular, instrumentation for the field method shall meet a Class I designation for octave-band filter sets and a Class II designation for third-octave band filter sets. Instrumentation for the laboratory method shall meet a Class II designation for octave-band filter sets and a Class III designation for third-octave band filter sets. Two other types of spectrum analyzers may be used for measurements using the field and laboratory methods. One type has a bandwidth which is a constant small fraction of the center frequency of the band. The other has a constant bandwidth.

5.5 Magnetic Tape Recorders. Instrumentation-grade magnetic tape recorders are useful for data storage and may be used to supplement the basic instruments described in 5.3.2 and 5.3.3.

5.5.1 Tape Recorder Characteristics and Operation. The electrical characteristics that are usually of critical importance in the choice of a tape recorder for noise measurements are the frequency response and the signal-to-noise ratio.

5.5.1.1 Frequency Response Characteristic. A frequency response characteristic that is uniform over the frequency range of 45 to 11 200 Hz is preferred. This response shall be checked frequently and adjusted for optimal uniformity. Corrections for the remaining irregularities shall be applied to the results of an analysis of the signal if third-octave or narrower bands are used.

5.5.1.2 Signal-to-Noise Ratio. The range in level from the internal noise level of the recorder to the level at which the distortion exceeds 2 percent shall be as wide as possible. The applied signal level must be set carefully in order to be within this range. If the applied signal is set too high, the recorded signal will be distorted, and subsequent measurements of the reproduced signal may be seriously in error. If the applied signal is set too low, the internal noise of the recorder may override the signal in the frequency ranges where the signal energy is low.

Since the signal-to-noise ratio is measured and specified in several different ways, a careful review of the significance of any particular specification shall be made for critical applications. The effect of the weighting characteristic (or preemphasis) on the signal to be recorded shall be considered.

5.5.1.3 Other Characteristics. In instrumentation recorders, the magnitude of the flutter shall be sufficiently small that measurements on the reproduced signal are not generally affected by it, unless filter bandwidths of 1 percent or narrower are used.

The phase characteristic of a system is ordinarily of little significance in acoustical measurements. In those instances where accurate reproduction of the recorded waveform is required, careful control of the phase characteristic is necessary, and the frequency-modulation process of recording is then the preferred procedure. For most noise-measurement applications either a direct-recording or a frequency modulation process may be used.

When the phase characteristic is important, the phase response of the system (including the recorder) shall ideally be an increasing linear function of frequency. Deviations from this ideal are frequently specified in terms of the delay (slope of the phase vs frequency curve) produced by the system.

The dynamic range of many systems will frequently be inadequate for the recording of nonsteady noise. For fluctuating and intermittent noise, recordings may be made at different levels on several recorder channels, or the system gain may be adjusted (either manually or automatically) during the period of observation. A method must be provided for determining the magnitude and time of occurrence of the gain changes. When recording quasi-steady noise, the signal peaks may be distorted because of the very high crest factors (for example, peak-to-rms ratios greater than 10) that are frequently encountered. A recording level must be chosen that makes a compromise between an adequate signal-to-noise ratio and excessive distortion of the signal.

5.6 Calibration and Maintenance of Instrumentation. The instruments used for the acoustical measurements shall be serviced at least once every twelve months in accordance with the manufacturer's instructions. This shall include checking the performance of all mechanical components and electrical circuits and replacing substandard items. The date c[illegible] most recent servicing shall be writte[illegible]n tags attached to the instruments. To ensure [illegible] the calibration of the equipment has not cha[illegible]uring a series of measurements, the ins[illegible]system shall be calibrated acoustically according to the manufacturer's instructions. A comparative calibration provided by a sound-level calibrator or pistonphone of known sound pressure level is usually satisfactory for this purpose. The frequency response of the complete instrumentation system shall be checked periodically to insure that the requirements of 5.4.2 are satisfied. For the laboratory method, microphones shall be calibrated by comparison with reference standard microphones which are calibrated according to American National Standard Method for the Calibration of Microphones, S1.10-1966 (see Section 12).

5.7 Precautions To Be Taken When Selecting Instrumentation

5.7.1 Precautions (Field and Laboratory Methods)

5.7.1.1 Wind (Field Method Only). To perform sound pressure level measurements in a moving air stream, a suitably designed windscreen or nose cone shall be utilized to minimize the influence of the air stream on the output of the microphone. No such precaution is necessary if the wind noise is 10 or more decibels below the signal being measured in each frequency band of interest. 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.

5.7.1.2 Humidity and Temperature. High humidity or temperature will change the sensitivity or damage many types of microphones. The microphone manufacturer's instructions shall be carefully followed to avoid such effects.

5.7.1.3 High Sound Pressure Levels. Many piezoelectric, moving-coil, and capacitor microphones may be used for the measurement of sound pressure levels up to approximately 140 dB re 20 $\mu N/m^2$. At higher levels, specially designed microphones with stiff diaphragms shall be used; these shall be calibrated at the levels to be measured and, if possible, over the entire frequency range of interest. At high sound levels, special precautions shall be taken to ensure that "microphonics" are not generated by the transmission of mechanical vibration to the microphone or instrumentation. These include:

(1) Installing the microphone and instrumentation on a soft mounting.

(2) Removing the instrumentation from the high sound levels and utilizing long cables; precautions are necessary to minimize cable noise, that is, the noise produced when the cable itself is subject to vibration or flexing.

(3) Installing the instrumentation behind suitable barriers or enclosures; a mechanically soft mounting shall be used for the low-sensitivity microphones that are utilized for the measurements of high sound levels.

(4) Determining electrical noise and possible "microphonics" problems by replacing the microphone with a highly insensitive (dummy) microphone.

5.7.1.4 Low Sound Pressure Levels. A microphone used to measure low sound pressure levels must have high sensitivity and low internal noise. When connected to suitable low-noise amplifiers, many piezoelectric, moving-coil, and capacitor microphones are suitable for measurements of sound pressure levels below 20 dB re 20 $\mu N/m^2$.

5.7.1.5 Low-Frequency Noise. Piezoelectric and some capacitor microphones are suitable for measuring sound pressures at frequencies down to fractions of a hertz. Special amplifiers are required for measurements of low-frequency noise. The low-frequency sensitivity of a microphone may vary considerably from the mid-frequency sensitivity due to the presence of a pressure-equalizing leak. Calibration shall be performed over the frequency range of interest.

5.7.1.6 High-Frequency Noise. For measurements above 20 000 Hz, miniature capacitor or piezoelectric microphones usually give the most satisfactory results.

5.7.1.7 Hum Pickup. When sound pressure levels are to be measured near electrical equipment, a moving-coil microphone shall not be used. The instrumentation shall be checked to make certain there is no hum pickup in the instruments themselves. Hum can be reduced by moving the instruments away from the source of the magnetic field or by selecting a proper orientation of the instruments with respect to the magnetic field.

5.7.1.8 Cables. When a cable is used between the microphone and the acoustical instrumentation, the system shall be calibrated according to the manufacturer's instructions with the cable in use.

5.7.2 Precautions (Survey Method). Sound-level meters with integral microphones are generally not suitable for a measurement program that requires the observance of the special precautions of 5.7.1.

5.7.3 Additional Effects on Measured Data

5.7.3.1 Effect of Observer and Meter Case on Measured Data

5.7.3.1.1 Survey Method. The sound-level meter shall be held in front of the observer. The observer shall be oriented with respect to the principal sound source so that the sound energy arrives at the microphone from the side unless some other orientation is specified by the instrument manufacturer.

5.7.3.1.2 Field and Laboratory Methods. In order to minimize the obstacle effect caused by the insertion into tne sound field of the sound-level meter and the experimenter holding it, the microphone shall be connected to the sound analysis equipment by means of an appropriate cable or extension connector and mounted on a tripod or other suspension system. The observer and all acoustical instrumentation except microphone(s), associated preamplifiers and cables should be located outside the test area.

5.7.3.2 Microphone Response and Orientation

5.7.3.2.1 General. The microphone calibration applied to compute sound pressure level shall conform to the way the microphone is used in the measurement; for example, free-field calibration at the appropriate angle of incidence. It should be recognized that microphone calibrations are often furnished in terms of the pressure response, which may differ from the free-field response at high frequencies by as much as 9.5 dB for one-inch diameter microphones.

5.7.3.2.2 Survey Method. See 5.7.3.2.1.

5.7.3.2.3 Field and Laboratory Methods. The microphone shall be oriented with respect to the source so that sound strikes the diaphragm at the angle for which the microphone was calibrated to have the flattest frequency response characteristic. The variation of the response with frequency shall be taken into account in each frequency band for maximum accuracy. It should be noted that microphones are usually most sensitive for sound propagating perpendicular to the microphone diaphragm. However, the angle required to obtain the flattest response vs frequency will be a function of the microphone design. It is imperative that reliable calibration data be used to determine the angle of operation for the flattest response. It should be noted that a microphone may be extremely sensitive at high frequencies to small changes in orientation for sound waves arriving parallel to the diaphragm. Therefore, during a measurement of sound which contains significant high-frequency components, it is advisable to maintain the microphone orientation to within ±5 degrees for the survey and field methods and to within ±2 degrees for the laboratory method.

6. Installation and Operation of Source

6.1 General. The requirements of this section are applicable only to measurements of sound sources. In many cases, the sound pressure levels in the vicinity of a source depend upon the support or mounting conditions and upon the manner in which the source is operated. This section gives general recommendations concerning installation and operation of sources. Reference shall be made to individual test codes for more detailed information concerning installation and mounting conditions of specific types of sources (for example, rotating electrical machines).

6.2 Installation of Source. Whenever a typical condition of mounting exists for the source, that condition shall be used or simulated, if practicable.

6.2.1 Method of Mounting. Many small sound sources (for example, ballasts for fluorescent lamps, electric clocks, etc) although themselves poor radiators of low-frequency sound, may, as a result of the method of mounting, produce marked increases in low-frequency sound when their vibrational energy is transmitted to surfaces large enough to be efficient radiators. Resilient mounting should be interposed if possible between the device to be measured and the supporting surfaces so that the transmission of vibration to the support and the reaction on the source are both minimized. However, such resilient mounts shall not be used if the device under test is not resiliently mounted in field installations.

6.2.2 Plane Reflecting Surfaces. When a source is mounted near one or more reflecting planes, its radiation impedance may differ appreciably from that of free space. If such a mounting is typical of field installations, the reflecting plane(s) shall be considered to be a part of the source. The optimal environment for a source mounted near one reflecting plane is a semi-anechoic room (free-field above a reflecting plane). See 3.4.3.4.

6.3 Operation of Source. During the acoustical measurements, the source shall be operated in a manner typical of normal use in a field installation. The following operational conditions may be appropriate:

(1) Device under normal load
(2) Device under full load (if different from (1))
(3) Device under no-load (idling)

6.4 Test Results. The conditions under which the source is installed and operated during the acoustical testing shall be described in the test results.

7. Microphone Positions

7.1 General. Microphone positions shall be selected so that an adequate sampling is obtained of the sound field in the ambient environment or in the vicinity of a sound source. The number of microphone positions selected shall be adequate to describe the ambient environment or specify the characteristics of the source.

7.2 Ambient Noise Measurements. When the microphone position is selected, the purposes of the measurements must be carefully considered. The microphone shall be located at those positions normally occupied by the ears of the people exposed to the sound field. These people may be standing sitting, or lying down. When it is desired to plot contours of equal sound pressure level, the required number of microphone positions will be determined by the degree of spatial irregularity in the sound pressure field and the resolution desired. The distance between microphone locations is to be specified in terms of the desired precision with which the ambient environmental levels are to be mapped.

7.2.1 Outdoors. The preferred height of the microphone above the ground for outdoor measurements is 1.5 meters. Other heights may be used if they prove to be more practicable. For example, in making measurements near an open window, the microphone shall be centered on the open window and at a horizontal distance of approximately 0.5 meter from the window.

7.2.2 Indoors. The preferred height of the microphone above the floor is 1.5 meters. Other heights may be used if they prove to be more practicable as, for example, in making measurements in a room where the occupants are normally seated (living rooms: microphone 1.1 meters above the floor) or lying down (bedrooms: microphone 0.6 meter above the floor).

7.3 Source Measurements. The distribution of sound in the vicinity of most sources is complex. Large noise-producing bodies may have surfaces which vibrate at many frequencies with many degrees of freedom. These bodies may produce sound pressure patterns that are extremely complicated. If the wavelength of the emitted sound is large compared with the dimensions of the source, the sound may be radiated uniformly in all directions. If the wavelength is short compared with the dimensions of the source, important directional effects and interference phenomena may appear. Hence, it may be necessary to determine the directivity characteristics as a function of frequency in order to completely specify the acoustical properties of the source.

The sound field of a source in the presence of one or more reflecting planes results from a superposition of the field of the actual source and that of the image source(s). The directivity pattern above a reflecting plane is generally more complex than that of the same source in a free field.

The number of microphone positions shall be sufficient to ensure that the sound pressure field in the vicinity of the source has been adequately described for the purposes of the measurements.

7.3.1 Operator Positions. If the source is attended by an operator, one microphone position shall be located at each operator position (preferably with the operator absent). If the operator stands, the microphone shall be at a specified height (for example, 1.5 meters) above the floor plane. If the operator is normally seated, the microphone shall be at a lower specified height (for example, 1.1 meters) above the floor plane.

7.3.2 Other Positions. In addition to the operator positions (if any), measurements shall be made at several locations in the vicinity of the source. When the source is not highly directional, measurements on four sides are frequently sufficient. When the source is highly directional, measurements at more than 20 different locations may be required. To locate the microphone, one of the following procedures may be used; the first procedure is suitable for both indoor and outdoor measurements; the second procedure is usually used for measurements outdoors when the microphone is a considerable distance from the source.

7.3.2.1 Rectangular Array of Microphone Positions. The smallest possible imaginary rectangular parallelepiped that will just enclose the source is utilized for reference purposes. At least one vertical side of the parallelepiped shall be parallel to one of the vertical surfaces of the source. Minor projections from the source are disregarded. The microphone positions are then specified with respect to the parallelepiped. The key measuring points are shown in Fig. 2. The microphone shall be located at each of the four key measuring points.

For small sources whose maximum linear dimension is less than 0.25 meter, the horizontal distance between the microphone positions and the parallelepiped is four times the maximum linear dimension of the source. Alternatively for small sources,

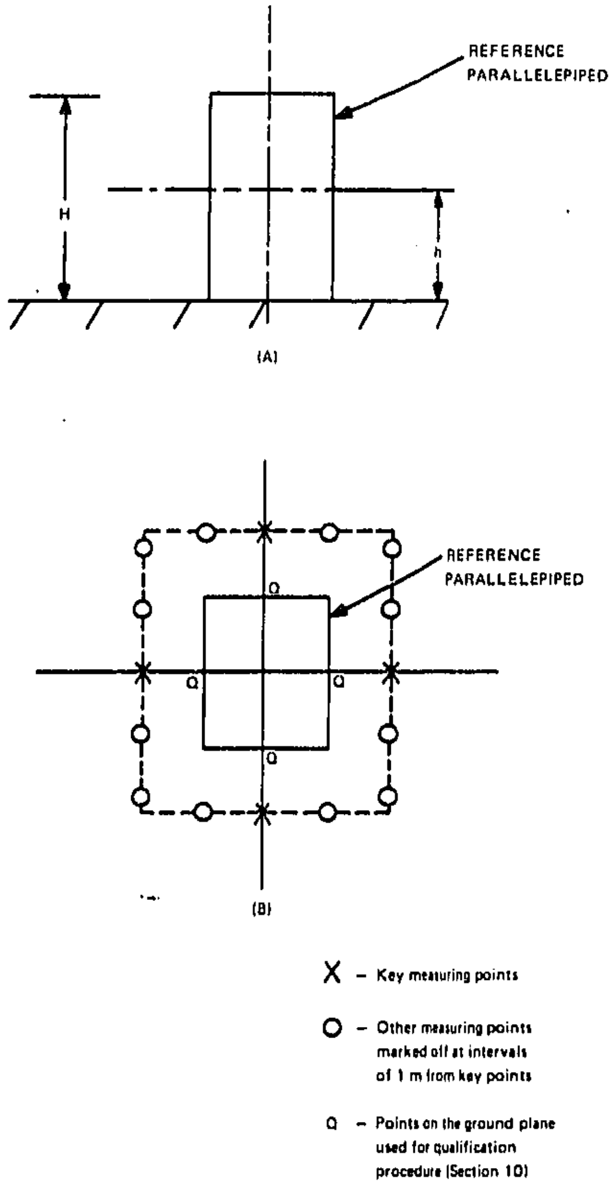


Fig. 2
Location of Measuring Points with Respect to Reference Parallelepiped
(A) Vertical Section
(B) Prescribed Positions in Horizontal Plane

the location of the four key measuring points may be described with respect to the center of the parallelepiped. For most sources whose maximum linear dimension is equal to or exceeds 0.25 meter, microphone positions located one meter from the parallelepiped are suitable. For large sources (or for sources that produce higher levels at greater distances than at one meter), it may be desirable to select a larger horizontal distance (for example, two meters) between the microphone positions and the parallelepiped.

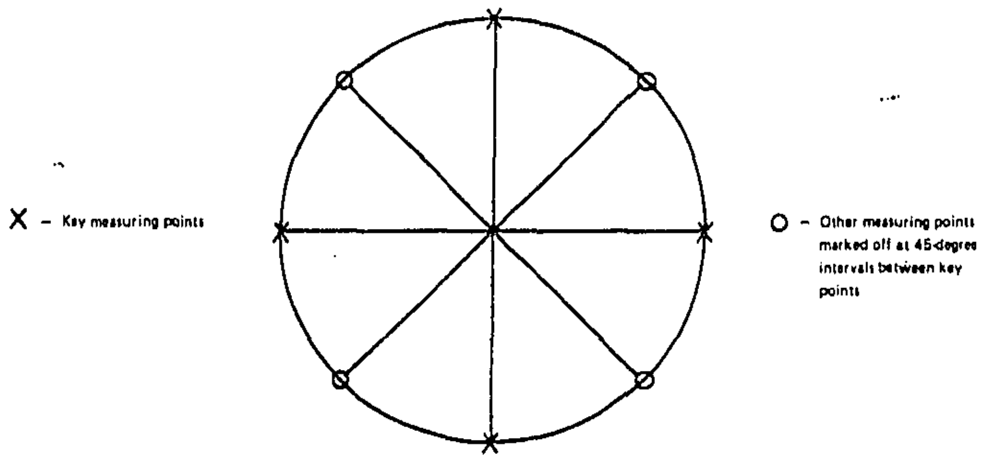
For large or highly directional sources, additional measuring points marked off at a suitable uniform interval (for example, one meter) from the key measuring points may be used as supplementary microphone positions. If this spacing results in two sets of microphone positions near the corners of the dotted rectangle of Fig. 2, it may be desirable to eliminate one of the two sets. The preferred height, h, of the microphone above the ground plane is 1.5 meters. For special applications, it may be more appropriate to select $h = H/2$, but not less than 0.25 meter.

7.3.2.2 Circular Array of Microphone Positions. The microphone positions are located on the circumference of a circle with the source at the center of the circle as shown in Fig. 3. The height of the microphone above the ground plane is determined in the same manner as for the rectangular array of microphone positions (see 7.3.2.1). As a minimum requirement, measurements on the periphery of the circle at angular displacements of 0, 90, 180, and 270 degrees in a horizontal plane shall be obtained. Measurements may also be made at intermediate points to adequately describe the sound field in the vicinity of the source. The radius of the circle shall preferably be more than five times the major source dimension, but never less than two times the major source dimension. Measurements at microphone positions around the complete circumference of the circle of Fig. 3 may not be required for sound fields known to exhibit spatial symmetries. When measurements at varying distances from the source are to be obtained, the distance of the microphone from the source shall be marked off at suitable uniform intervals on either a logarithmic scale (preferred) or a linear scale.

7.3.3 Microphone Positions for Sound Power Determinations. If a determination of sound power is desired, microphone positions shall be selected according to American National Standard S1.2-1962.

7.3.4 Microphone Positions for Moving Sources.

Fig. 3
Location of Measuring Points in Alternate Prescribed Pattern



The microphone positions used shall be those of 7.2 and 7.3. For moving sources, the microphone may be oriented so that the highest sound pressure is incident on the diaphragm from the direction for which the microphone was calibrated. Alternatively, the orientation may be such that the sound pressure from the moving source impinges on the microphone diaphragm at the same angle of incidence throughout the period of observation. The relative position of the source with respect to the microphone, particularly the distance of closest approach, shall be specified.

7.3.5 Microphone Positions for Sources That Contain Audible Discrete Tones. When audible discrete tones are present (see Appendix A), the microphone shall be moved in order to reduce the effects of localized interferences (see 8.3).

8. Measurement of Steady and Nonsteady Noise

8.1 General. The purpose of this section is to provide quantitative guidelines for determining the type of noise (that is, steady or nonsteady) being measured, and to prescribe methods for reading the meter of a noise-measuring instrument. Variations in the output of noise sources combined with short-term environmental changes affecting sound propagation result in fluctuations of the sound level. The meter does not respond instantaneously when a signal is presented to it; the reading at any instant depends upon the amplitude of the signal a short time before, the amount of damping that has been applied to the meter movement, and the rate at which the level is changing. Two ballistic characteristics are normally provided for a sound-level meter: "fast" and "slow." The "fast" meter characteristic has a response time of approximately 0.1 second, and the response time of the "slow" meter characteristic, obtained by increasing the meter damping, is approximately 1 second. The meter characteristics are specified more precisely in American National Standard S1.4-1971. When the fluctuations of the meter with the "fast" characteristic are greater than ±3 dB, the "slow" position shall be used. Exceptions to this rule are discussed in 8.4.

8.2 Procedures for Measuring Steady Noise Without Audible Discrete Tones

8.2.1 Measurement Procedure. When measurements of steady noise are made in a frequency band that does not contain an audible discrete tone, the level corresponding to the rms sound pressure during the period of observation is of greatest interest. When the fluctuations of the indicating pointer on the sound-level meter are less than ±3 dB using the "slow" meter characteristic, the noise is considered to be steady, and the level is taken to be the average of the maximum and minimum levels during the period of observation. A situation may arise when the use of the "fast" meter characteristic indicates that the level fluctuates between two or more well-defined steady levels less than 6 dB apart. In this case, the procedures of 8.4.2.4 may be used.

8.2.2 Data To Be Obtained. For steady noise in frequency bands that do not contain an audible discrete tone, the following data shall be obtained.

8.2.2.1 Survey Method. At each microphone position (see Section 7), the sound level (with A or other appropriate weighting) shall be obtained. No effort is required to control or change the acoustic environment.

8.2.2.2 Field Method. At each microphone position (see Section 7), an octave-band or third-octave band analysis shall be obtained. Exceptions to this requirement are discussed in 11.2. No weighting shall be used for these analyses. If desired, the sound level (with A or other appropriate weighting) may be recorded. For outdoor measurements of sources, environmental conditions shall approximate as closely as possible those described in 3.4.2. For indoor measurements of sources, environmental conditions shall approximate as closely as possible those described in 3.4.3 unless it is desirable or necessary to work under the conditions of 3.4.4, in which case environmental conditions shall be fully described.

8.2.2.3 Laboratory Method. At each microphone position (see Section 7), an octave-band or third-octave band analysis shall be obtained. Exceptions to this requirement are discussed in 11.2. No weighting shall be used for these analyses. If desired, the sound level (with A or other appropriate weighting) may be recorded. The measurements shall be performed in an anechoic (or semi-anechoic) room that meets the requirements of 3.4.3.

8.3 Procedures for Measuring Steady Noise with Audible Discrete Tones

8.3.1 Measurement Procedure. Standing waves or large spatial variations in sound pressure are frequently produced by sound sources that radiate audible discrete tones (see Appendix A). In a free field, standing waves may be created by interferences between sound waves generated at two or more separated areas on the surface of a large source. In a free field above a reflecting plane, destructive interferences will also occur at those locations where the difference between the length of the direct path and the path reflected from the plane is an odd multiple of a half wavelength. Indoors, standing wave interferences may be particularly pronounced unless the room is extremely large or optimized as described in 3.4.3.

At a particular point in such an interference field, the sound pressure level in a frequency band containing the discrete tone is rarely relevant except when evaluating the effect of noise from a fixed source on an observer whose position with respect to the source and all reflecting surfaces is clearly defined. Even then it must be borne in mind that the interference field will shift in space with slight changes of temperature (speed of sound) or frequency (machine speed). Usually it is more relevant to measure either the maximum or the rms sound level (or rms sound pressure level) during the period of observation for a suitable choice of microphone positions.

To reduce the influence of localized interferences, the microphone may be moved along circular arcs in a vertical plane with arc lengths of at least $\lambda/2$ and preferably greater than λ where λ is the wavelength of the sound at the audible discrete frequency of interest. The microphone shall be moved at a rate of at least one traverse per second, but with a velocity less than two meters per second to avoid the effects of wind noise. The motion of the microphone shall not generate noise or vibration that affects the sound pressure level readings. The center point of each arc shall pass through the measuring points of Section 7 and the arc radius shall be at least one meter. The microphone shall continue in motion about each measuring point for a sufficient period of time to permit an average reading to be obtained with the "slow" response setting of the meter. Alternatively, the true rms pressure along the path may be determined by direct computation using analog or digital techniques.

To evaluate regions of maximum sound level, the microphone shall be moved slowly along a path connecting the measuring points shown in Fig. 2 or Fig. 3 while simultaneously reducing the influences of localized interferences as described above.

8.3.2 Data To Be Obtained. When audible discrete tones are present, a narrow-band analysis shall be performed. In frequency bands that contain an audible discrete tone, the maximum and average sound level or sound pressure level observed during each traverse of the microphone shall be obtained. If the sound pressure level fluctuates due to beats between noise sources, the "slow" setting of the meter movement shall be used; the maximum (and minimum) sound pressure level produced by spatial and temporal fluctuations shall be reported. These data are obtained in addition to the data described in 8.2.2 for frequency bands that do not contain an audible discrete tone.

8.4 Procedures for Measuring Nonsteady Noise

8.4.1 General. Noises that are nonsteady are classified in 4.2.2 as fluctuating noise, intermittent noise, isolated bursts, or quasi-steady noise.

Two kinds of temporal fluctuations shall be distinguished. For the first kind, the noise fluctuates between two or more well-defined steady levels as, for example, could occur during the cyclic operation of a machine. The length of time the noise remains steady at each of the well-defined levels is sufficient to obtain an estimate of the average value for each level using the "fast" meter characteristic. For the second kind, the level fluctuates continuously over a wide range. For example, noise levels near a busy highway may fluctuate over a range of 30 dB or more, and the level does not remain at a steady level for an appreciable length of time during the period of observation.

An intermittent noise is usually "on" for a time long enough to determine an average level using the "fast" meter characteristic. The "on" periods may occur at regular or irregular intervals during the period of observation, and the noise level may be steady or may fluctuate during the "on" period.

There are two distinctly different approaches to the measurement of intermittent noise. The conventional approach utilizes standard instrumentation, and is described in this section. Alternatively, the intermittent noise may be treated as a burst or series of bursts, and the methods of Appendix B may be used.

Quasi-steady noise is a series of impulses whose repetition rate is sufficiently high that the noise can be considered as steady (see 8.2).

It is often difficult to distinguish between isolated bursts and quasi-steady noise. When 10 or more impulses occur each second, the noise is nearly always quasi-steady, and may be conveniently measured with the equipment used for steady noise described in Section 5. When one impulse per second or less occurs, the noise nearly always consists of isolated bursts, and may be measured using the techniques described in Appendix B.

In the range 1-10 impulses per second, the distinction is much less clear. An estimate of the average level, the magnitude of the fluctuations in sound pressure level, and an oscilloscope photograph of the envelope of at least 10 bursts are useful, and provide a description of the noise. A calibration of the vertical scale of the oscilloscope in terms of sound pressure or sound pressure level shall be made.

8.4.2 Measurement Procedures. Because the characteristics of nonsteady noise are difficult to define quantitatively, the procedure to be followed in reading the sound-level meter will vary with the ultimate use of the measured data. The type of data desired usually falls into one of five categories.

(1) An estimate of the level corresponding to the true rms value of the sound pressure (rms level) for a specified period of observation. (See 8.4.2.1.)

(2) An estimate of central tendency (for example, the average level) during the specified period of observation. (See 8.4.2.2.)

(3) An estimate of the maximum and minimum levels (using the "fast" or "slow" meter characteristic) during the specified period of observation. (See 8.4.2.3.)

(4) An estimate of the level during the "on" time of an intermittent noise, or an estimate of the levels that occur when a noise fluctuates between two or more well defined values. (See 8.4.2.4.)

(5) An estimate of the variations in level with time. (See 8.4.2.5.)

Data are obtained by observing the fluctuations of the pointer on the meter of the noise-measuring instrument. The observed readings are not independent because a finite time is required for the pointer to assume a new value. When using the "fast" meter characteristic, at least one-half second shall be allowed between observations; when using the "slow" meter characteristic, the interval between observations shall be at least two seconds.

8.4.2.1 Estimates of the Level Corresponding to True rms Sound Pressure. If the fluctuations of the pointer on the indicating meter are between ±3 dB and ±5 dB ("slow" meter characteristic), the level corresponding to the rms sound pressure is approximately 3 dB below the maximum level; when successive excursions are observed to have different maximum levels, the level is approximately 3 dB below the mean of the maximum levels for several excursions. If the range of the fluctuations is greater than ±5 dB, the estimate of the level is less certain; it may deviate from the true value by several decibels. An estimate may be obtained by reading the sound level meter 10 or more times during the period of observation. The level is estimated from the following equation:

$$L = 10 \log \frac{1}{N} \sum_{i=1}^{N} 10^{\frac{L_i}{10}} \qquad \text{(Eq 1)}$$

where

N = the total number of observations

L_i = the level at each observation

If the time scale of the fluctuations is such as to make this procedure impractical, other techniques such as direct computation of the rms pressure by analog or digital means are required.

NOTE: A useful rule-of-thumb is that the number of observations shall equal the range of the fluctuations in decibels.

8.4.2.2 Estimates of Central Tendency. The average indication of the meter may be estimated by following the procedure of 8.4.2.1 and using the following equation:

$$L = \frac{1}{N} \sum_{i=1}^{N} L_i \qquad \text{(Eq 2)}$$

to estimate the average level. A better estimate of the average level may be obtained if the average is taken only over the middle 50 percent of the readings.

The method of averaging shall be reported with the test results. If the time scale of the fluctuations is such as to make this procedure impractical, and the fluctuations are less than ±5 dB, the average of the maximum and minimum readings approximates the average level.

8.4.2.3 Estimates of Maximum and Minimum Level. The maximum and minimum level during the period of observation can be determined by observing the meter using the "fast" or "slow" characteristic. When the time required for a variation from minimum to maximum is five seconds or more, the "slow" meter characteristic may be used. For more rapid variations, the "fast" meter reading is more relevant.

8.4.2.4 Variations in Steady Level. For intermittent noise that varies between two or more well-defined steady values when observed using the "fast" or "slow" meter characteristic, the rms level for each steady value is usually of interest, and can be obtained using the "slow" meter characteristic when the level is steady for five seconds or more. For levels that are steady for one to five seconds, the "fast" meter characteristic shall be used. For shorter bursts, the maximum value of the "fast" meter reading shall be recorded, or the noise shall be treated as impulsive or quasi-steady.

8.4.2.5 Determination of the Variations in Level with Time. The survey method is not useful if the history of level variations is to be determined because a recording device is required. The electrical and mechanical characteristics of the device shall be such that the history of the fluctuations of the indicating meter can be determined.

8.4.3 Data To Be Obtained

8.4.3.1 Survey Method. If the noise is fluctuating between two or more well defined values, the value at each level shall be recorded. If the level fluctuates constantly over a range greater than ±3 dB using the "slow" meter characteristic, the maximum and minimum values and the rms or average level shall be recorded.

If the noise is intermittent, the level during the "on" period is usually of greatest interest. The average or rms level during the "on" period shall be recorded.

If the noise is quasi-steady, it may be treated as steady noise with the exception that the system gain shall be adjusted so that the level is measured at the lowest possible position on the indicating meter scale. The meter may read on scale if the system gain is increased by 10 dB. However, many instruments will produce an inaccurate reading because of the high crest factor usually encountered in quasi-steady noise.

8.4.3.2 Field and Laboratory Methods. A magnetic tape recording may be obtained of the non-steady noise. To perform the frequency analysis, the tape recording shall be played back through the instrumentation system containing a spectrum analyzer, and a separate playback shall be made each time the selected frequency of the analyzer is changed. Alternatively, an endless loop of tape may be used for the analysis, or a parallel set of analyzers having the desired bandwidth characteristics may be used.

A description of the filter outputs as a function of time depends upon the nature of the signal. For fluctuating noise having two or more well-defined steady levels, the rms levels can be estimated for each frequency band of interest.

For noise levels that fluctuate continuously over a wide range, the maximum and minimum levels shall be determined, and the rms or average level shall be estimated.

For intermittent noise, the average or rms level during the "on" time shall be estimated in each frequency band of interest.

For quasi-steady noise, the methods of 8.4.1 shall be used. The peak levels should, however, be monitored with an oscilloscope to ensure that no clipping occurs in the amplifying or recording systems.

9. Corrections for Ambient Noise During Source Measurements

9.1 General. The ambient sound pressure level with the source not operating shall, if possible, be determined at typical microphone locations in all frequency bands. If the increase in the sound pressure level in any given band, with the source operating, compared to the ambient sound pressure level alone is 15 decibels or more, the sound pressure level due to both the source and ambient sound is essentially the sound pressure level due to the source alone. This is the preferred condition, but is frequently unattainable in the field.

If the increase in sound pressure level in any given band, with the sound source operating, compared to the ambient sound pressure level is 3 decibels or less, the sound pressure level due to the sound source is equal to or less than the ambient sound pressure level, and the two contributions cannot be properly separated with the measuring techniques described in this standard.

9.2 Survey and Field Methods. If the increase in sound pressure level in any given band, with the sound source operating, compared to the ambient sound pressure level, is between 4 and 15 decibels, the sound pressure level due to the sound source may be approximated by applying the corrections listed in Table 4. These corrections are based on the assumption that the indicating meter gives a close approximation of the value of the rms sound pressure level. It is also assumed that the ambient sound pressure and the sound pressure due to the sound source are incoherent and can therefore be added on a pressure-squared basis. When the contributions from source and ambient sound are partially coherent, phase relations are important and corrections in general terms cannot be stated.

9.3 Laboratory Method. Since precision measurements are carried out under controlled environmental conditions, the combined level of the ambient noise and the instrument noise shall be at least 10 decibels and preferably 15 or more decibels below the sound pressure levels generated by the source in each band within the frequency range of interest.

10. Qualification Procedures for Indoor Environments

10.1 Procedure When Source Can Be Moved. One useful qualification procedure for checking items (1) and (2) in 3.4.4.1 is to remove the source under evaluation, and to place a reference sound source at selected points whose locations are defined with respect to the rectangular parallelepiped (see 7.3.2.1 and Fig. 2). The reference source shall have dimen-

Table 4
Corrections for Ambient Sound Pressure Levels

Difference (in Decibels) Between Sound Pressure Level Measured with Sound Source Operating and Ambient Sound Pressure Level Alone	Correction (in Decibels) To Be Subtracted From Sound Pressure Level Measured with Sound Source Operating To Obtain Sound Pressure Level Due to Sound Source Alone
4	2.2
5	1.7
6	1.3
7	1.0
8	0.8
9	0.6
10	0.4
11	0.3
12	0.3
13	0.2
14	0.2
15	0.1

NOTE: For the survey and field methods, corrections of less than 0.5 dB are seldom necessary. For the laboratory method, a measurement shall not be considered valid if the correction exceeds 0.5 dB. Exceptions to the latter requirement are discussed in 11.2.2.

sions that are small compared with the wavelength of sound at the lowest frequency of interest, shall radiate broad-band sound energy having no audible discrete tones, and shall be relatively omnidirectional. The sound pressure level produced by the reference source shall be at least 10 dB above the ambient level in the frequency bands of interest.

The reference sound source shall be operated on the floor at each of the points Q on the parallelepiped shown in Fig. 2. The sound pressure levels at the key measuring points shall be compared with the sound pressure levels measured at convenient intervals (for example, 0.25 meter) along a line passing through each key measuring point and perpendicular to the surface of the parallelepiped. The closest point of measurement shall be 1 meter from each key measuring point (for example, 2 meters from the parallelepiped). If at one or more points along the line the level is at least 6 dB below the level at the key measuring point, the direct sound energy will usually be sufficiently greater than the reflected sound energy that the environment approximates a free field over a reflecting plane for survey and field measurements. If the difference is less than 6 dB, the room can often be modified to meet this objective by covering the walls and other large surfaces near the measuring points with sound absorptive materials.

10.2 Procedure When Source Cannot Be Moved. If the source being evaluated cannot be removed from the test site, or if the sound pressure level produced by the reference sound source is not 10 dB above the ambient levels produced by the source undergoing evaluation, the measurement procedure of 10.1 may be followed using the actual source instead of the reference source.

NOTES:

(1) The second procedure (10.2) will be difficult to use if the source radiates audible discrete tones. The space averaging procedure of 8.3.1 shall be used to ensure that a minimum in the interference pattern is not taken as representative of the sound field at the key or other measuring points.

(2) If the environment is not or cannot be qualified according to one of the above procedures, this information shall be reported with the test results.

11. Reporting Sound Pressure Level Data

11.1 General. The following information, when applicable, shall be compiled and reported for measurements that are made according to the requirements of this standard.

11.1.1 Sound Source Under Test (Source Measurements Only)

(1) Description of the sound source under test

(2) Operating conditions

(3) Mounting conditions

11.1.2 Acoustic Environment (Indoors)

(1) Location of sound source(s) (if any)

(2) Dimensions of test room; description of the physical treatment of the walls, ceiling, and floor; sketch showing the location of source(s) and room contents

(3) Qualifications of test room (see Sections 3.4.4 and 10)

(4) Air temperature in degrees Celsius, relative humidity in percent, and barometric pressure in

millimeters of mercury (field and laboratory methods only)

11.1.3 Acoustic Environment (Outdoors). (Survey and field methods only.)

(1) Location of sound source(s) (if any)

(2) Dimensioned sketch and photograph(s) of the test area showing buildings, trees, structures, and other reflecting objects

(3) Physical and topographical description of the ground surface

(4) Meteorological conditions at a specified height above the ground: air temperature in degrees Celsius, relative humidity in percent, barometric pressure in millimeters of mercury, wind direction in degrees of azimuth, and average wind speed in meters per second

11.1.4 Instrumentation

(1) The equipment used for the measurements, including name, type, serial number, and manufacturer

(2) Bandwidth of frequency analyzer (field and laboratory measurements only)

(3) Frequency response of instrumentation system including weighting used (if any)

(4) The time response of the measuring system; that is, "slow," or "fast" response, or alternate appropriate description

(5) For the field and laboratory methods, the method used to calibrate the microphone and the date and place of calibration

11.1.5 Acoustical Data

(1) The locations and orientation angles of the microphone (a sketch shall be included if necessary).

(2) The sound pressure levels obtained, for all frequency bands or weightings, or both, used, in decibels with reference 20 $\mu N/m^2$. When appropriate, the maximum, minimum, and estimated average or rms sound pressure levels shall be reported as required by 8.4.3.

(3) The corrections in decibels, if any, applied in each frequency band to account for the frequency response of the microphone, frequency response of the filters, ambient noise, etc.

(4) The corrected sound pressure levels shall be tabulated or plotted to the nearest decibel for survey and field measurements and to the nearest half decibel for laboratory measurements. For plotting the results of measurements obtained with the field and laboratory methods, suggested formats are given in Fig. 4 for octave- and third-octave band analyses and in Fig. 5 for narrow-band analyses. The scale length on the ordinate of Figs. 4 and 5, corresponding to a 10:1 frequency ratio on the abscissa, is equal to 10, 25, or 50 dB.

(5) The duration of the period of observation.

(6) For source measurements, the sound pressure levels in decibels of the ambient environmental noise with the source not in operation shall be given re 20 $\mu N/m^2$.

(7) The date and time when the measurements were performed.

11.2 Comparison of Data. When the data obtained from measurements made according to the requirements of this standard are to be compared with other acoustical data, great care shall be exercised to ensure the validity of the comparison.

11.2.1 Comparison with Other Measured Values. In order for a valid comparison to be made, it is imperative that the conditions under which the two sets of data were obtained be as nearly identical as is practicable. Section 11.1 lists the information to be compiled and reported as part of a series of sound pressure level measurements. It is particularly important that the environmental conditions as well as the operating and mounting conditions for the source (if any) be nearly identical.

11.2.2 Comparison with Prescribed Values. Frequently, sound pressure level measurements are made to determine how the measured data compare with a prescribed value or set of values. Four different techniques, based on sound pressure level data obtained at a given microphone position, are commonly used to obtain the values to be compared. In some cases, field or laboratory measurement of the sound level may be all that is required for comparison with prescribed values. In this case, octave- or third-octave band data are not required. If no interference effects are present, the ambient noise requirements of Section 9 may be relaxed. However, the measured level will not be that of the source alone, and in the presence of interference effects the level measured with the source operating may be lower than the ambient level.

11.2.2.1 Octave- or Third-Octave Band Levels. The sound pressure levels prescribed for comparative purposes may be specified in either octave bands or third-octave bands over the frequency range of interest. Lower and upper cut-off frequencies of 45 and 11 200 Hz are usually adequate. However, special circumstances may require the use of higher or lower cut-off frequencies for the filter set. The levels prescribed for comparative purposes may be given on an octave-band or third-octave basis. Only the field and laboratory methods yield octave- or third-octave band data that may be used for comparative purposes.

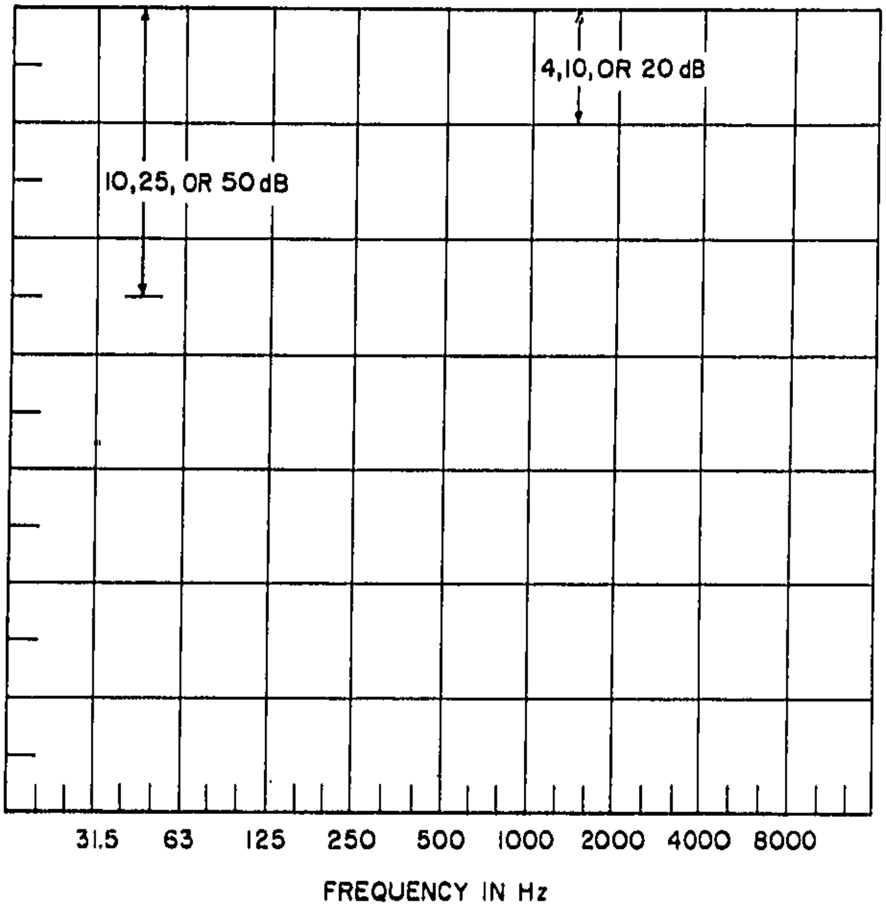


Fig. 4
Preferred Format for Reporting Octave- and Third-Octave Band Measurements of Sound Pressure Level

11.2.2.2 Sound Levels. The sound-level value prescribed for comparative purposes may be, for example, sound level A. The measured value may be obtained by using either the survey, field, or laboratory methods. Alternatively, an approximation to the measured value may be obtained with the field or laboratory methods by applying corrections to each octave- or third-octave band level. The resultant mean-square pressures in each band are then added and converted to a logarithmic quantity such as sound level A. Shapes of standard weighting curves are given in American National Standard S1.4-1971. It is not recommended that the calculation procedure be used when audible discrete tones are present in the spectrum of the noise.

11.2.2.3 Band Selection. The value prescribed for comparative purposes may be based on a band selection method. Measured octave band sound pressure levels are converted to new values by means of an equation, a set of tables, or a family of curves.

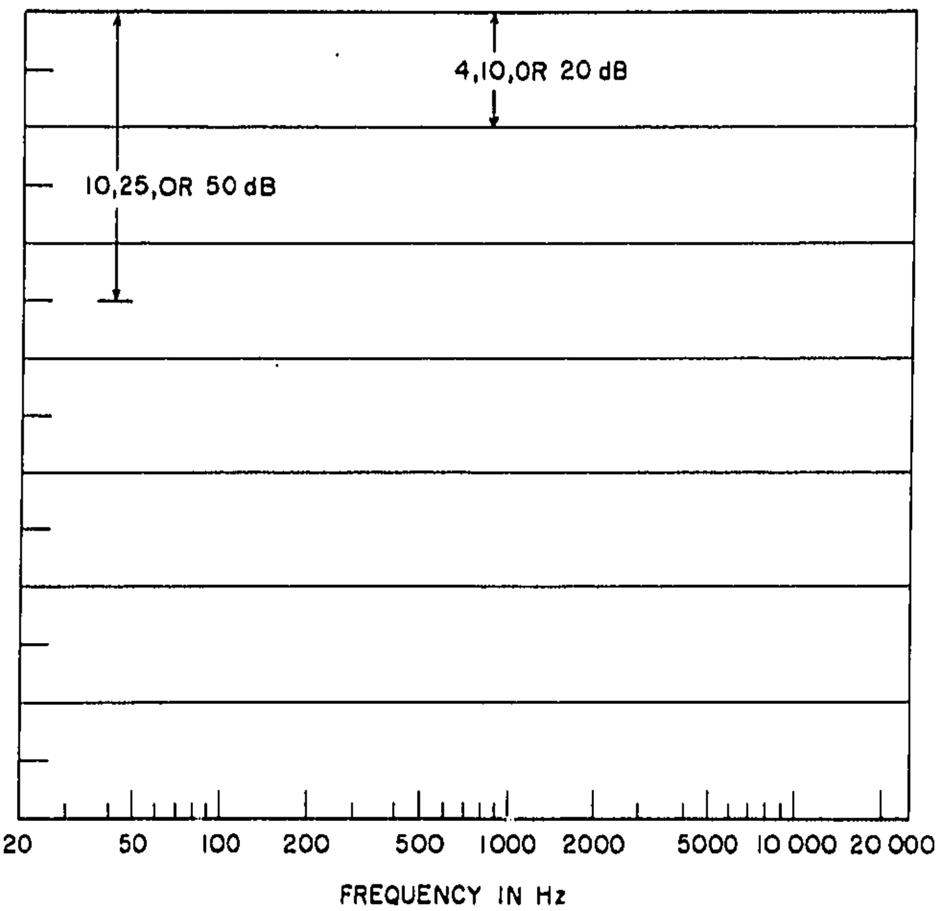


Fig. 5
Preferred Format for Reporting Narrow-Band Measurements of Sound Pressure Level

The highest number calculated by this procedure is usually selected as the single-number value. Data that are converted by this technique must be obtained using either the field or laboratory methods. A correction is often applied if audible discrete tones are present in the spectrum.

11.2.2.4 Band Summation. The value prescribed for comparative purposes may be based on a band summation method. Measured octave- or third-octave band sound pressure levels are converted to new numerical values. These numbers are then added with suitable weighting. It is common practice to use a weighting of 1.0 for the highest number, and smaller weightings for the remaining numbers. The resulting sum may be converted to a logarithmic unit. For example, the band pressure levels may be converted to loudness index, weighted and summed to yield a loudness in sones, and then converted to a calculated loudness level in phons.

(Reference: American National Standard Procedure for the Computation of Loudness of Noise, S3.4-1971 [see Section 12].) Data that are converted by this technique must be obtained by either the field or laboratory methods. A correction is often applied if audible discrete tones are present in the spectrum.

11.2.2.5 Band Averaging. The value prescribed for comparative purposes may be based on a band averaging method. Measured octave band sound pressure levels covering a restricted frequency range are arithmetically averaged to obtain a single-number value. This value is then compared with the prescribed value. Data that are converted by this technique must be obtained using either the field or laboratory methods.

11.2.3 Choice of Methods for Comparing Data. Data obtained by the survey method may be compared by use of the procedures prescribed in 11.2.2.2 only. Data obtained using the field or laboratory methods may be compared using any of the techniques described in 11.2.2. For diagnostic analyses which are undertaken to establish a basis for engineering action when noise control is desired, the techniques described in 11.2.2.1 and 11.2.2.3 have proven useful. For relating measured sound pressure level data to the subjective effects of noise, the techniques described in 11.2.2.4 and 11.2.2.5 have proven useful.

12. Revision of American National Standards Referred to in This Document

When the following American National Standards referred to in this document are superseded by a revision approved by the American National Standards Institute, the revision shall apply:

American National Standard Acoustical Terminology, S1.1-1960

American National Standard Method for the Physical Measurement of Sound, S1.2-1962 (R1971)

NOTE: American National Standard S1.13-1971 represents a revision of Section 2 of American National Standard S1.2-1962.

American National Standard for Sound Level Meters, S1.4-1971

American National Standard Preferred Frequencies and Band Numbers for Acoustical Measurements, S1.6-1967

American National Standard Preferred Reference Quantities for Acoustical Levels, S1.8-1969

American National Standard Method for the Calibration of Microphones, S1.10-1966

American National Standard Specification for Octave, Half-Octave and Third-Octave Band Filter Sets, S1.11-1966

American National Standard Specifications for Laboratory Standard Microphones, S1.12-1967

American National Standard Procedure for the Computation of Loudness of Noise, S3.4-1971

Appendixes (These Appendixes are not a part of American National Standard Methods for the Measurement of Sound Pressure Levels, S1.13-1971, but are included to facilitate its use).

Appendix A
Identification of Prominent Discrete Tones

A1. Prominent Discrete Tones

A discrete tone will be audible in the presence of wide-band noise if its sound pressure level exceeds the sound pressure level of the noise in a Fletcher critical band centered at that frequency. In general, the tone is just audible (at its masked threshold) when its level equals that of the noise in the Fletcher critical band centered at the frequency of the tone (Reference 1). This is the relationship used to define the width of the Fletcher critical band, and it is valid for masking noises having continuous spectra without excessive slopes. Noise spectra obtained using constant percentage bandwidth filters having slopes greater than approximately 10 dB per octave (particularly negative slopes and high levels) may produce remote masking for which the Fletcher critical band concept is not valid. A prominent discrete tone may be defined as a tone whose level is a specified number of decibels (X) or more above the level at which the discrete tone would be just audible in the presence of wide-band continuous noise. In many practical situations, a discrete tone would be classified as "prominent" by a panel of listeners if the specified number of decibels (X) is between 5 and 15. The value of X must be selected by the user of this procedure.

To determine if a discrete tone is prominent, the filter of the narrow-band analyzer used for the measurements should have a bandwidth that is approximately equal to or less than the width of the Fletcher critical band, f_c (see Table A1). A prominent discrete tone is present if the sound pressure level of the tone measured with a filter of bandwidth Δf is at least $[X - 10 \log_{10} (\Delta f/f_c)]$ dB above the arithmetic average of the band pressure levels measured on each side of the discrete tone. The term $10 \log_{10} (\Delta f/f_c)$ relates the band pressure level measured with a band Δf in width to the width of the Fletcher critical band f_c. The value of X is the specified number of decibels in the definition of a prominent discrete tone.

The curve of Fig. A1 may be used to identify a prominent discrete tone with a constant percentage bandwidth analyzer (approximately 7 percent) when X is specified as being 10 dB. The response of the narrow-band analyzer is down 3 dB at ±3.5 percent of the selected frequency.

As it is not always obvious at what frequency the sound pressure levels should be chosen in order to obtain the arithmetic average of the band pressure levels on each side of the discrete tone, the measurement procedure requires clarification. In the ideal case of a discrete tone superposed on wide-band continuous noise, the selectivity curve characteristic of the filter in the narrow-band analyzer will be traced with its center at the frequency of the discrete tone. If the observed band pressure level versus frequency curve deviates from the selectivity characteristic of the narrow-band analyzer at the frequency of the discrete tone, this is an indication that multiple discrete tones or narrow bands of noise are present. The procedure of Section A2 should be followed.

Table A1
Fletcher Critical Bandwidths (f_c) as a Function of Frequency

Frequency (Hz)	f_c (Hz)
100	87
200	52
315	50
400	50
630	53
800	58
1000	63
1250	71
1400	76
1600	83
1800	91
2000	98
2500	123
3150	150
3550	173
4000	204
6300	404
8000	589
10 000	832

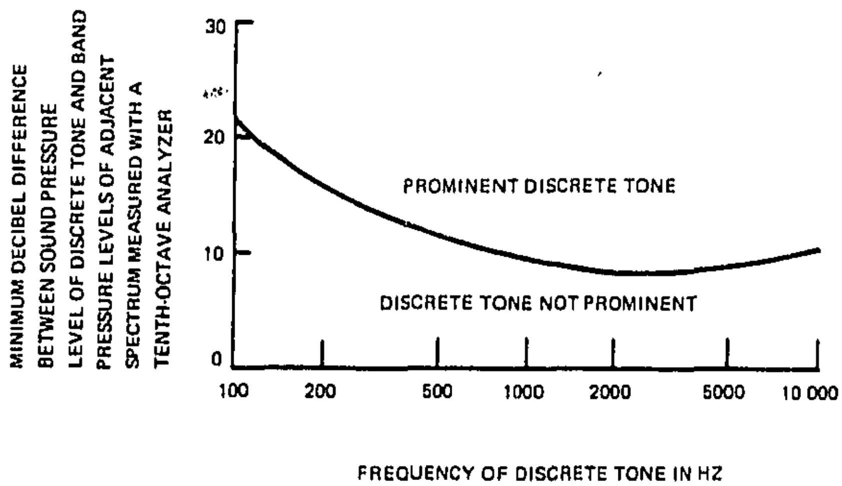


Fig. A1
Criterion for the Prominence of a Discrete Tone
Based on Tenth-Octave Bandwidth

A2. Narrow Bands of Noise

From a practical standpoint, no distinction need be made between multiple discrete tones clustered together and narrow bands of noise. However, a narrow band of noise may be distinguished from a single discrete tone if the width of the narrow band as plotted can be distinguished from the bandwidth of the analyzer. Considerable judgment must be exercised in selecting the frequencies on either side of the narrow band of noise at which the arithmetic average is to be calculated. It is usually appropriate to select points that are between ±2 and ±4 bandwidths from the selected frequency (for example, if a 7 percent analyzer is set to 1000 Hz, the points at which the average is taken should be 140 to 280 Hz above and below 1000 Hz).

A3. Alternate Procedure

Another procedure for identifying prominent discrete tones in the presence of broadband noise is described in Reference 2.

References to Appendix A

(1) FLETCHER, H. *Speech and Hearing in Communication.* New York: D. Van Nostrand Co, Inc, 1953, p 101.

(2) Section B36.3, Federal Aviation Regulations. Published in the Federal Register, vol 34, no. 221, Nov 18, 1969.

Appendix B
Measurement of Impulsive Noise (Bursts)

B1. Introduction

In practice, sources that produce an impulsive sound are frequently encountered. If the duration of the impulse is sufficiently long, the noise may be analyzed by the methods described in Section 8. However, the duration of an impulse is usually less than one second, and is frequently less than 0.5 second. The methods described in Section 8 are therefore not applicable. When a standard sound-level meter is used to measure a short impulse, the meter will show a momentary rise and decay, but the maximum reading obtained is commonly 15 to 30 dB below the peak pressure level of the sound wave.

In Section 8, the characteristic of the noise of primary interest is usually the value of the effective (rms) pressure of the sound wave. In dealing with impulses of short duration, other characteristics are also of interest. For airborne impulsive noise, the envelope of the pressure versus time pattern is generally of greatest interest. Fig. B1 shows a typical impulsive noise burst.

To define methods for assessing the effects of impulsive-type noise, a considerable amount of experimental data must be accumulated. The collection of these data has been hampered by the lack of well-defined parameters to specify the characteristics of a burst as well as a simple technique for measuring these parameters. The peak pressure level and the burst duration are of major importance. For certain applications, measurements of the values of other parameters may also be of value, and are described elsewhere. (See Reference 1.)

B2. Categories of Impulsive Noise

Impulsive noise is readily identified by an observer when only a single burst occurs during the period of observation (see 4.2.2.3.1 of the standard) or the time interval between acoustic impulses is long. The human ear is less valuable as a guide when a distinction is to be made between quasi-steady noise with a high burst repetition rate (see 4.2.2.3.2 of the standard) and steady noise. The distinction in this case should be made in terms of specified values of the parameters that characterize the impulsive noise.

B2.1 Example of Classification of Impulsive Noise. To be classified as impulsive noise, an individual burst must have a duration of less than 0.25 second measured between the instants at which the instantaneous sound pressures have a value equal to one-half the peak value. If the noise is repetitive, the repetition rate of the bursts must be less than 5 per second and the arithmetic average of the peak sound pressure levels (determined using an A-weighting network) of 10 consecutive bursts in the train, must be more than 15 decibels above the A-weighted sound pressure level in the presence of the impulses.

B3. Instrumentation (Field and Laboratory Methods)

For the reasons given in Section B1, instrumentation appropriate for the survey method should not be used. A typical instrumentation system that is appropriate for burst measurements is shown in Fig. B2. This system consists of a microphone, a wide-band amplifier, a spectrum analyzer or weighting networks, an oscilloscope (with camera) and a peak-reading circuit. The microphone and wide-band amplifier should be of laboratory quality; their combined frequency response should be uniform over a frequency range whose lower limit is less than half the lowest frequency of interest and whose upper limit is more than twice the highest frequency of interest. The peak value of the sound level or sound pressure level may be determined with the aid of a peak-reading circuit. The rise time of the peak detector should be less than 200 μs and of such a value that a single pulse of 200 μs duration produces a meter deflection no more than 4 dB below the deflection produced by a reference pulse having a duration of 10 μs and equal peak amplitude. The amplitude of the 10 μs reference pulse should be such as to produce a full-scale (+0, −1 dB) meter deflection. The peak value can also be obtained with the oscilloscope. The oscilloscope is included in the system to facilitate the measurement of the values of other parameters that may be of interest. It is useful if the oscilloscope is equipped with a memory or storage feature, a single sweep capability and a camera to obtain a permanent record for later analysis. The oscilloscope sweep may be synchronized to a timing signal derived either from an electrical signal related to the burst or to an acoustical signal.

In this section, the only instrumentation described is that for burst display. Photographs of such displays may be used to obtain the values of the burst parameters of interest. Alternatively, hybrid methods (a combination of analog and digital techniques) may be used to measure and store burst parameters. Or, digital processing may be utilized to analyze the characteristics of a burst after it has been converted from analog to digital form. However, these methods lie outside the scope of this document.

B4. Microphone Positions

The same considerations as discussed in Section 7 are applicable. However, burst measurements in the near-field of an impulsive-noise source are frequently of interest. For this reason, it may be desirable to make measurements at positions closer to the source than those described in Section 7.

B5. Types of Measurement (Field and Laboratory Methods)

Wide-band waveforms with the spectrum analyzer of Fig. B2 removed from the measuring system are usually of greatest interest; however, the burst may also be observed at the output of the analyzer, for example, with an A-weighting network in the analyzer. A single burst (pressure-time pattern) incident on the microphone will produce an envelope that is highly dependent on the bandwidth and center frequency of the analyzer since the rise time and decay time of the filters are defined by these parameters. It is not clear that the observed peak pressure level in a particular band has real significance by itself, since this peak is not one that actually occurs in a typical sound wave. Nevertheless, the peak pressure level in a band may give a useful indication of the frequency distribution of the sound energy. (See Reference 2.)

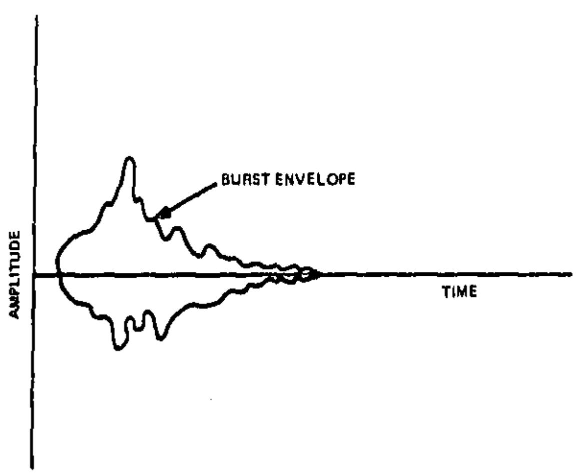
The characteristics of a burst that are usually of greatest interest include the burst duration and the magnitude of the burst (either peak, average, or rms). Other parameters of interest and methods of measurement are given in Reference 1.

References to Appendix B

(1) Institute of Electrical and Electronics Engineers. Recommended practices for burst measurements in the time domain. IEEE No. 257. May 1964.

(2) PETERSON, A.P.G. The measurement of impact noise. *General Radio Experimenter*, vol 30, no. 9, 1956.

Fig. B1
Typical Burst of Sound Pressure



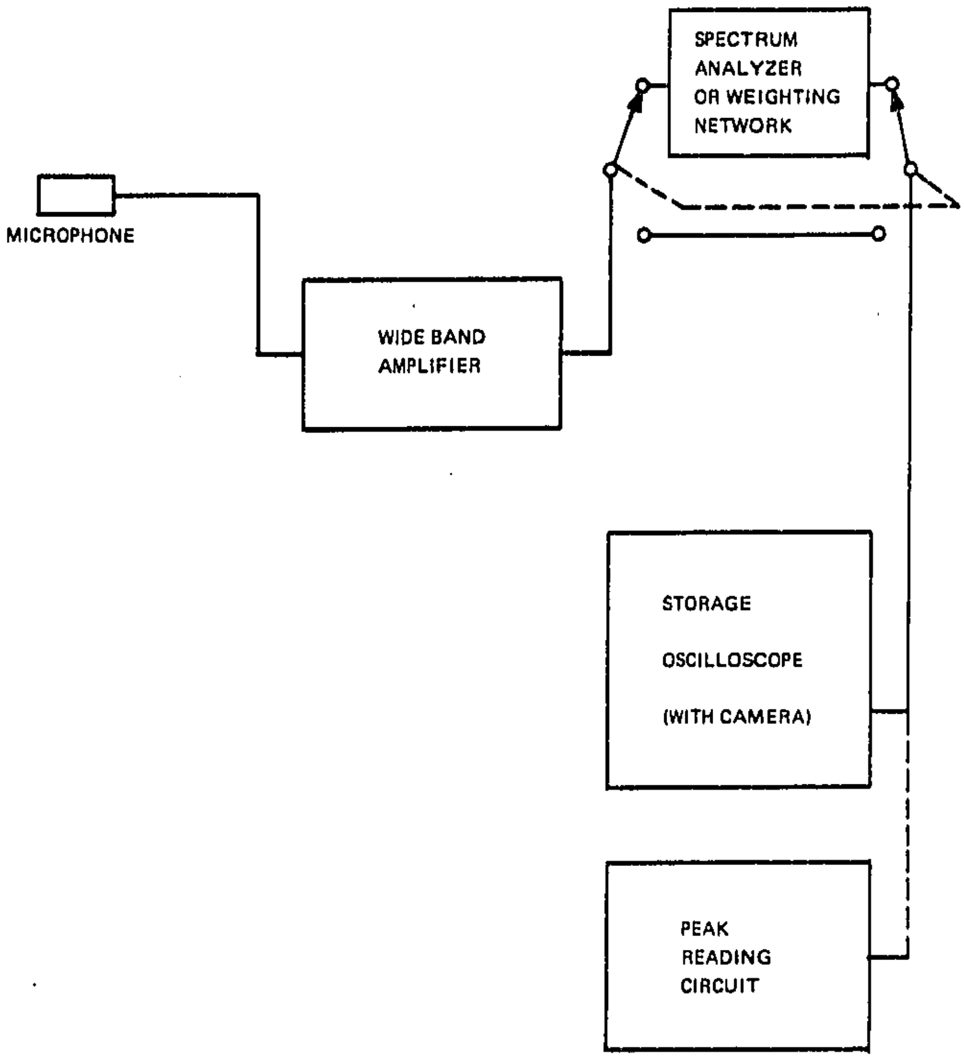


Fig. B2
Instrumentation for Burst Measurements

American National Standards

The standard in this booklet is one of nearly 4,000 standards approved to date by the American National Standards Institute, formerly the USA Standards Institute.

The Standards Institute provides the machinery for creating voluntary standards. It serves to eliminate duplication of standards activities a[illegible] [illegible]weld conflicting standards into single, nationally accepted stan[illegible] [illegible]e designation "American National Standards."

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