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AMERICAN NATIONAL STANDARD
Quantities and Procedures for Description and Measurement of Environmental Sound. Part 2: Measurement of long-term, wide-area sound

ACCREDITED STANDARDS COMMITTEE S12, NOISE

ABSTRACT

This standard is the second in a proposed series of parts concerning description and measurement of outdoor environmental sound. This standard describes recommended procedures for measurement of long-term, time-average environmental sound outdoors at one or more locations in a community for environmental assessment or planning for compatible land uses and for other purposes such as noise prediction validation and regulation. Sound may be produced by one or more separate, distributed sound sources such as a highway, factory, or airport, or by all contributing sound sources. For spatial or temporal samples of environmental sound in a community, requirements are given for the number of sound-measurement locations and the duration of the sound-sampling intervals needed to obtain average values for long-term environmental sound levels that are within stated accuracy limits for Class A, Class B, or Class C measurements. The purpose of this standard is to provide for a commonality for measurements of outdoor environmental sound as it may affect people in and around dwellings.

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The Acoustical Society of America provides the Secretariat for Accredited Standards Committees S1 on Acoustics, S2 on Mechanical Shock and Vibration, S3 on Bioacoustics, and S12 on Noise. These committees have wide representation from the technical community (manufacturers, consumers, and general-interest representatives). The standards are published by the Acoustical Society of America through the American Institute of Physics as American National Standards after approval by their respective standards committees and the American National Standards Institute.

These standards are developed and published as a public service to provide standards useful to the public, industry, and consumers, and to Federal, State, and local governments.

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FOREWORD

[This Foreword is not a part of American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound. Part 2: Measurement of long-term, wide-area sound, ANSI S12.9-1992/Part 2 (ASA Catalog No. 105-1992).]

This standard has been developed under the jurisdiction of Accredited Standards Committee S12, Noise, using the American National Standards Institute (ANSI) Accredited Standards Committee Procedure. The Acoustical Society of America provides the Secretariat for Accredited Standards Committee S12, Noise.

Accredited Standards Committee S12, Noise, under whose jurisdiction this standard was developed, has the following scope:

> Standards, specifications, and terminology in the field of acoustical noise pertaining to methods of measurement, evaluation, and control, including biological safety, tolerance, and comfort, and physical acoustics as related to environmental and occupational noise.

This standard is the second in a proposed series of parts concerning description and measurement of outdoor environmental sound. This standard describes recommended procedures for measurement of long-term, average environmental sound levels outdoors at one or more locations in a community. The first part in this series is ANSI S12.9-1988, American National Standard Quantities and Procedures for Description and Measurement of Outdoor Environmental Sound. Part 1. The first part deals largely with definitions for standard quantities; this new part deals largely with procedures.

This series uses the three parts of ISO 1996-1987, Description and Measurement of Environmental Noise, as a point of departure, but there are marked differences.

At the time this standard was submitted to Accredited Standards Committee S12, Noise, for approval the membership was as follows:

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Suggestions for improvements in this standard will be welcomed. They should be sent to **Accredited Standards Committee S12, Noise, at the Standards Secretariat, in care of the Acoustical Society of America, 335 East 45th Street, New York, NY 10017-3483. Telephone (212) 661-9404.**

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American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound. Part 2: Measurement of long-term, wide-area sound

1 SCOPE

This standard describes recommended procedures for measurement of long-term, time-average environmental sound outdoors at one or more locations in a community for environmental assessment or planning for compatible land uses and for other purposes such as noise prediction validation and regulation. Sound may be produced by one or more separate, distributed sound sources such as a highway, factory, or airport, or by all contributing sound sources. For spatial or temporal samples of environmental sound in a community, requirements are given for the number of sound-measurement locations and the duration of the sound-sampling intervals needed to obtain average values for long-term environmental sound levels that are within stated accuracy limits for Class A, Class B, or Class C measurements.

2 PURPOSE

The purpose of this standard is to provide for a commonality for measurements of outdoor environmental sound as it may effect people in and around dwellings.

3 APPLICATIONS

This standard is applicable to measurement of outdoor environmental sound in a community. Typical applications include:

(a) assessment of the general community noise environment and establishment of baseline environmental sound levels;

(b) evaluation of the general noise environments of various areas within a city, or determination of areas of greatest noise impact;

(c) identification of the principal community sound sources responsible for major contributions to the general noise environment;

(d) comparison of the environmental sound levels in a city with those in other cities;

(e) measurement of environmental noise levels with respect to the evaluation of public attitudes toward noise, or the results of a noise attitudinal survey;

(f) development of a technical basis for a community noise reduction strategy which might include various measures such as educational programs, a noise ordinance, housing site setbacks from heavily traveled roads, and the inclusion of barrier walls and beams around proposed housing developments;

(g) guidance for environmental sound measurement elements of planning land use, and highway traffic rates and patterns;

(h) providing the technical basis for measurement of environmental sound levels to be included in associated enforcement efforts;

(i) demonstration of compliance with community noise limits established by cognizant local, state, or federal departments or agencies; and

(j) repeat measurements of community sound levels to determine trends or effectiveness of noise control efforts.

4 REFERENCES TO OTHER STANDARDS

[The following standards contain provisions which, through reference in this document, constitute provisions of this American National Standard. At the time of approval by the American National Standards Institute, Inc. (ANSI), the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this American National Standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below.]

(1) ANSI S12.40-1990, American National Standard Sound Level Descriptors for Determination of Compatible Land Use.

(2) ANSI S12.4-1986 (R 1993), American National Standard Method for Assessment of High-Energy Impulsive Sounds with Respect to Residential Communities.

(3) ANSI S1.13-1971 (R 1986), American National Standard Methods for the Measurement of Sound Pressure Levels.

(4) ANSI S12.7-1986 (R 1993), American National Standard Methods for Measurements of Impulse Noise.

(5) ANSI S12.9-1988 (R 1993), American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound. Part 1.

(6) IEC 804:1985, Integrating-Averaging Sound Level Meters.

(7) ANSI S1.40-1984 (R 1990), American National Standard Specification for Acoustical Calibrators.

(8) IEC 942:1988, Sound Calibrators.

5 DEFINITIONS

5.1 Spatial Sampling

5.1.1 deterministic spatial sampling: sampling of sound levels at measurement sites selected by person(s) who believe the levels at these sites to be representative of the sound levels in the total area from which the sites are selected.

5.1.2 systematic spatial sampling: sampling of sound levels at measurement sites selected by a predetermined, statistically unbiased procedure, for example, at equally spaced points along a line (linear systematic sampling), at logarithmically spaced points along a line (logarithmic systematic sampling), or at the intersection points of an orthogonal grid of lines (two-way linear systematic sampling).

5.1.3 random spatial sampling: sampling of sound levels at randomly selected measurement sites.

5.1.4 stratified spatial sampling: sampling of sound levels at measurement sites classified by a spatial criterion such as land use and selected according to a random or systematic technique. Two types of stratified spatial samples include:

(a) **simple stratified:** each sampling area in a community is divided into as many subsampling areas as there are spatial criteria under consideration. Sound levels in each subsampling area are sampled independently of those in other areas.

(b) **quota stratified:** total area is randomly sampled until the respective number of sites for each criterion are selected.

5.1.5 multi-stage spatial sampling: sampling of sound levels at measurement sites selected by combinations of sampling techniques in which the community is divided into study areas. Subsets of these study areas are selected as study areas for sound measurements by one sampling technique. Measurement sites for sampling of sound levels are chosen from within each selected study area using a second sampling technique.

5.1.6 cluster spatial sampling: cluster spatial sampling is a specific variation of multi-stage spatial sampling. A specific set of small study areas, called clusters, is selected from the community using one sampling technique. No study areas are defined for the remainder of the community. Measurement sites for sampling of sound levels are chosen from within each selected study area using either the same or another sampling technique.

5.2 Survey Area

5.2.1 macro survey area: a sufficiently large geographic area such that the *exact* location of any selected sound measurement site is not important. For example, in a macro survey area any housing lot in a selected block or neighborhood may be an equally good sound measurement site. The size of a macro survey area ranges from a few city blocks to an entire community.

5.2.2 micro survey area: a sufficiently small geographic area such that variations in the location of a measurement site either horizontally or vertically can affect the measured long-term, time-average environmental sound level. For measurement of traffic noise, a typical micro survey area includes an intersection and the streets leading into the intersection.

5.3 Noise Zone

A noise zone is a collection of all areas exposed to sounds produced by a particular kind of noise source, and typically comprises several geographically noncontinuous areas. For example, the ensemble of all commercial and industrial areas within a community constitutes the commercial–industrial noise zone. No location within a community may be categorized by more than one noise zone. When more than one significant noise source is present in a given area, the noise source with the highest day–night average sound level, in the absence of any other sources(s), shall be used to identify the type of noise zone. One noise zone may contain, be contained by, or traverse another.

5.3.1 airport noise zone: collection of all areas in which aircraft activity is predicted to produce a day–night average sound level equal to or greater than a specified level such as 65 decibels (dB).

5.3.2 railroad noise zone: those areas which comprise the collection of linear strips extending on each side of well-traveled railroad tracks. The width of a railroad noise zone is a function of railroad activity according to the following guideline (The width corresponds to the outer boundary of a day–night average sound level contour of approximately 65 dB for a railroad track at ground level, without any trackside noise barriers, carrying typical rail traffic. However, this is only a rough approximation and is not intended to replace a rigorous noise analysis of railroad environmental sound levels.):

Equivalent number of train operations per day $N = N_{day} + 10\,N_{night}$	Railway noise zone width from the track centerline (meters)
less than 5	No railroad zone
5 to 7	30
8 to 10	45
11 to 16	60
17 to 19	75
20 to 35	90
36 to 50	120
51 to 80	150
81 to 140	180
141 to 250	240
251 to 400	300

Railroad yards are considered stationary sources and are not included within a railroad noise zone.

5.3.3 roadway noise zone: collection of those areas which comprise linear strips extending on each side of a roadway, the width of which is a function of the type of roadway or the average daily traffic count in all lanes. Roadway zones are classified as follows (The width corresponds to the outer boundary of a day–night average sound level contour of approximately 65 dB for a roadway at ground level, without any noise barriers, carrying typical road traffic. However, this is only a rough approximation and is not intended to replace a rigorous environmental sound analysis of roadway noise levels.):

Average daily traffic (ADT)	Roadway noise zone width from outer edge of pavement (meters)
less than 1200	6
1200 to 4000	12
4000 to 12 000	25
12 000 to 36 000	50
greater than 36 000	100

5.3.4 commercial–industrial noise zone: collection of those areas not falling within airport, railroad, or roadway noise zones in which the predominant land use is commercial or industrial.

5.3.5 stationary source noise zone: those areas not falling within airport, railroad, roadway, or commercial–industrial noise zones in which noise from large stationary sound sources predominate.

5.3.6 residential noise zone: collection of those areas not falling within airport, railroad, roadway, commercial–industrial, or stationary source noise zones in which the predominant land use is residential. Subclasses of a residential noise zone based upon population density are as described in the following table:

Density description	Density (people/kilometer^2)
Very low	less than 300
Low	300 to 800
Medium	800 to 2400
High	2400 to 7000
Very high	greater than 7000

NOTE: The commercial–industrial noise zone (see Sec. 5.3.4) and the residential noise zone (see Sec. 5.3.6) are established for purposes of implementing spatial sampling procedures as defined in Sec. 8.3. These two zones are not necessarily distinguished by any sound source(s) within the zone itself.

5.4 Other Spatial Noise Zones

5.4.1 enclave noise zone: a small geographic area of the community characterized by a cultural, historical, political, or geographical unity for which a characterization of average environmental sound levels is desired.

5.4.2 district noise zone: regions into which communities may be divided based upon geographical factors and considered independently of noise zones.

5.5 Measurement Site and Microphone Location

5.5.1 measurement site: the localized area within which the sound level measurements are taken.

5.5.2 microphone location: the exact position of a microphone.

5.6 Autocorrelation

5.6.1 autocorrelation function: a function, $A(\tau)$, of time delay, τ, that indicates the degree of likeness between a continuous function or time-sampled set of data and the same function or time-sampled set of data, delayed by τ seconds for a continuous function, or time lagged by τ time units for a time-sampled set of data.

5.6.2 time lag: unit of observation time, ΔT, for a series of time-sampled sound levels. For typical community noise measures such as day–night average sound level, the unit of observation, ΔT, is one 24-hour day.

5.7 Accuracy

5.7.1 class A survey:

(a) **spatial:** a sound-level survey designed to achieve a spatial accuracy of $\pm$ 3 dB with a confidence interval of 95 percent (%).

(b) **temporal:** a sound-level survey designed to achieve temporal accuracy of $\pm$ 50% in sound exposure with a confidence interval of 95%.

5.7.2 class B survey:

(a) **spatial:** a sound-level survey designed to achieve a spatial accuracy of $\pm$ 5 dB with a confidence interval of 95%.

(b) **temporal:** a sound-level survey designed to achieve a temporal accuracy of $\pm$ 90% in sound exposure with a confidence interval of 95%.

5.7.3 class C survey: for spatial or temporal sampling, a class C survey is designed to define an upper limit to the environmental sound levels, the highest level or worst case.

6 DATA ACQUISITION FOR LONG-TERM, WIDE-AREA SOUND LEVELS

6.1 General

Long-term sound measurements of a specific source such as a particular jet aircraft, a specific class of sound sources such as the vehicles on a highway, or the overall level for all contributing sources are normally made for describing and quantifying the typical or average levels; not the highest levels. Thus, these measurements should span the typical range of operations of the source(s), and they should span a full range of meteorological conditions as they affect the sound source(s) and the propagation of sound. For example, if a particular measurement site is located such that 50% of the time it is normally downwind from the source of sound and 50% of the time it is normally upwind, then the measurements shall include both wind conditions with roughly their normal percentage of occurrence. As a second example, if the sound measurements were for a highway, the measurement shall include both busy commuting days and less busy weekends.

6.2 Acoustical Instrumentation Selection, Operation, and Calibration

Instrumentation selection, operation, and calibration shall generally follow the procedures and recommendations of ANSI S1.13-1971 (R 1986), Methods for the Measurement of Sound Pressure Levels.

6.2.1 Sound Level Meters. Instruments to be used to measure environmental sound levels in a community shall meet the Class 1 accuracy requirements of IEC 804. For measurement of sound exposure levels, equivalent continuous sound pressure levels, and day–night average sound levels, integrating instruments meeting the Class 1 requirements of IEC 804 shall be used.

6.2.2 Calibration. Acoustical calibrators used to establish the acoustical sensitivity of a sound-measuring system at a specified calibration frequency shall comply with the Class 1 (or Type 1) accuracy requirements of ANSI S1.40-1984 (R 1990) or IEC 942.

6.2.3 Windscreens. Windscreens which are effectively acoustically transparent (less than ±0.5 dB effect over the frequency range of interest) shall be used when it can reasonably be expected that the pseudo-sound of the wind generated signal will be within 10 dB of the average sound level from the sound source(s).

6.3 Meteorological Instrumentation and Measurements

Because the normal purpose of long-term monitoring is to measure typical conditions, measurements of long-term average sound levels in accordance with the scope of this standard do not normally require accompanying direct, on-site measurements of local meteorological conditions. However, as such measurements of long-term average sound levels are often made by unattended, automatic sound-measuring systems, some information on local meteorological conditions may be helpful in interpreting anomalous or questionable data. For example, it is necessary to know of high winds which cause excessive wind-induced noise, rain or other precipitation which can affect the microphone, freezing rain or ice which can cover the windscreen or microphone, snow cover when it is not part of the range of typical conditions, and other weather conditions or effects which can bias the measurements. When needed, information on prevailing local meteorological conditions may often be obtained from public agencies or private concerns that regularly measure and record meteorological data on, for example, an hourly basis or as maximum and minimum conditions on a daily basis. However, in very special cases where local geological features such as large bodies of water or major terrain features may directly affect the sound-level measurements, then some form of on-site meteorological data gathering may be required.

7 PROCEDURES FOR MEASURING AND MONITORING ENVIRONMENTAL SOUND

7.1 General

Community noise measurement programs vary in complexity, duration of measurements, and spatial coverage depending on the purpose, scope, and desired accuracy of the measured sound levels. The many ways in which community noise may vary with sound sources, time, and measurement position shall all be considered along with a clear statement of the purposes of the measurements.

7.2 Measurement of Total Ambient Sound Level versus Sound Level from Specific Sources

Community noise measurements may be applied to many situations as described in Sec. 3. However, the measurements may be grouped into two broad categories:

(a) measurement of some attribute of the total ambient sound environment; and

(b) measurement of sound from a specific source such as an airport, highway, or factory.

Measurements of the total ambient sound level may be undertaken to verify that a site meets environmental sound level requirements for a proposed land use, or to monitor long-term community noise trends, etc. Measurement of the total ambient sound is normally the simplest type of community measurement since all noises at a site are included in the measurement.

The more difficult situation is the measurement of sound from a specific source. In this case, one must ensure that the acoustical measurements include virtually all of the sound produced by the source under study without including significant sound from any other sources. For example, one may wish to sample sound near an airport as part of an airport land use compatibility study. A purpose of the measurements may be to compare measured data with computer-predicted sound levels. Thus, the measurements shall be such that:

(1) sound from all other sources (vehicle traffic, for example) is of sufficiently low level that it does not appreciably increase the average sound level measured; or

(2) the desired sound sources shall be individually identified and shall be of high enough level such that the contribution of individual sound sources later may be separated from sound caused by other community sources.

Regardless of the measurement purpose, care shall be taken that the measurements are acquired over representative periods of time (see Sec. 9).

7.3 Specific Source Measurements

7.3.1 Unmanned versus manned measurements. Community sound level measurements of a specific source can be accomplished only with careful selection of sites and periods of measurement. Successful measurements may require observers to be stationed at sites, the gathering of source operational information (times and directions of aircraft flights, or times of factory operations, etc.), or complex acoustical and nonacoustical signal processing.

For example, measurements near an airport may have two monitors in a line near an aircraft flight path. Identification of aircraft data may be based upon correlation of sound events in the correct time sequence for an aircraft departure or arrival, with appropriate temporal spacing between events at the two monitors. In this case, observers may not be needed to identify sound from aircraft flights. However, if the type of aircraft or operation is of interest, observers, or other information about the aircraft operations, will be needed.

If it is necessary to identify specific sound events, observers should generally be used, unless specific information as to the times of occurrence can be obtained from other sources. Although the use of observers at sites avoids many of the problems of source identification inherent in unmanned measurement programs, the costs associated with manned monitoring may be prohibitive when spatial (see Sec. 8) and temporal (see Sec. 9) requirements are taken into account.

NOTE: Aerospace Recommended Practice (ARP) 4721 provides additional specific guidance on the monitoring of noise in the vicinity of airports.[1]

7.3.2 Time correlations. To provide adequate identification of sound sources, community sound level measurements shall identify the time of specific sound events, the sound level of the event, and the level of background noise. Commercial instrumentation exists that can perform these functions, and also allows the operator to select a sound-level threshold. When the sound level rises above the threshold, an event is defined and the measurement period begins. The duration of the event above the threshold, the sound exposure level, the maximum frequency-weighted sound level, and the time of occurrence for the maximum level of the event should be measured and recorded.

7.4 Microphone Locations

This section discusses the placement of microphones for individual site measurements. The overall selection of numbers and locations of measurement sites for surveys over an extended area is discussed in Sec. 9.

7.4.1 Vertical microphone placement. Microphones shall be located, in general, at a height of 1.2 ± 0.1 meters (m) above the ground. Alternatively, the microphone may be located within 0.03 m of the ground. The height selected shall be stated. In areas where at least one-fourth of the population lives or works at elevated locations, the microphone height may be increased to a height midway between the first and highest occupied floor of a representative building (e.g., for a three-story apartment, the microphone height could be increased to be approximately 1.2 m above the floor of the second story). Alternatively, several measurements at 1.2 ± 0.1 m above ground (or within 0.03 m of the ground) can be augmented with a few measurements at one or more elevated heights to determine the variation of sound level with height. When measuring at both ground and elevated levels at the same location, the same spacing away from the building facade shall be maintained for all sets of measurements.

7.4.2 Horizontal microphone placement. For total ambient sound-level measurements in built-up areas, the location closest to the nearest roadway shall be chosen from the following two choices:

(a) 15 meters from the centerline of the nearest traffic lane; or

(b) 3 meters from the nearest building facade toward the roadway.

For total ambient sound level measurements in more or less open land (only occasional buildings), the measurement location shall be chosen from the following three choices:

(a) 15 meters from the centerline of the nearest traffic lane or roadway center for unmarked roadways;

(b) 30 meters from the centerline of the nearest lane of a limited access highway right-of-way; or

(c) 30 meters from the nearest rail of a railroad right-of-way.

For specific source measurements, horizontal microphone placement is governed by the following major considerations:

(a) minimizing the influence of other local sound sources on the measurements; and

(b) minimizing the influence of reflections of sound from nearby buildings or obstructions.

Thus, for aircraft noise measurements, a measurement site should be chosen at the rear of a dwelling rather than in the front in order to reduce the influence of local roadway traffic sounds. For industrial sound-source measurements, one should avoid (or separately account for) the diffraction of sound radiation from the source by intervening buildings or obstacles.

8 SPATIAL SAMPLING REQUIREMENTS

8.1 General

Measurement site selection depends on the purpose of the measurements, the predominant source being monitored, and the sampling strategy. When possible, computer modeling shall be used to identify the source or sources which contribute significantly to the sound at each measurement site.

8.2 Measurement Sites

8.2.1 Built-up areas. For all residential, commercial–industrial, and stationary source noise zones, measurement sites shall be at randomly selected locations formed by the intersection of orthogonal grid lines spaced 0.3 kilometers (km) apart which are not coincident with any dominant street pattern. Adjustment of the grid spacing or the specific measurement location at a site may be necessary to:

(a) avoid concentration in any one type of geographic area;

(b) ensure that the sound level samples span the range of population density for the entire sample area;

(c) avoid sites which have limited or difficult access; and

(d) include, if feasible, one or more sites at a residence, school, hospital, or any other noise-sensitive area.

8.2.2 Roadway noise zones. For each roadway noise zone, measurement sites shall be randomly selected points drawn from a linear array of points constructed every 0.3 km lying along each roadway within each roadway zone.

8.2.3 Railroad and limited-access highway noise zones. For railroad and limited-access highways, one site selected by deterministic means is sufficient for each set of measurement conditions, which include grade, terrain, elevation or depression of track or roadway, and the size and density of surrounding buildings.

8.2.4 Airport noise zones. Computer-generated predictions are normally used to determine the size and shape of an airport noise zone. Measurements are normally used to verify or adjust the predicted aircraft sound levels. Measurement sites should be selected with respect to the computer-generated, predicted noise zone map and the measurement purpose. Individual airports are too unique for general spatial sampling rules.

8.3 Spatial Sample Determination

For each of the noise zones identified for the community, determine the minimum number of noise monitoring sites by one of the following methods.

8.3.1 Procedural method.

	Number of sites required	
Noise zone type	Class B survey	Class A survey
Residential (all densities)	8	30
Roadway (all traffic volumes)	6	20
Commercial or industrial	9	42
Stationary source	9	42
Railroad	see Sec. 8.2.3	
Airport	see Sec. 8.2.4	

NOTE: All of the above noise zone types describe large distributed sound-producing geographic locations. These requirements are not intended to be applied to small, geographically compact sources of sound such as a single backup generator of electrical power or a small electrical power substation, etc.

8.3.2 Iterative method. For all noise zones, except airport and railroad, select at least 2/3 of the number of sites stated in Sec. 8.3.1. After acquiring the minimum number of sound level samples, compute the standard deviation of the measured long-term average sound levels for each site. If the standard deviation (± 3 or ± 5 dB) or confidence interval (95%) is outside of the tolerance permitted for the survey class according to the requirements of Sec. 5.6, then sound levels shall be measured at additional randomly selected sites. To the extent possible, the same site selection procedures employed for the initial sample should be employed for selection of the additional measurement sites. Measurement sites shall be added until the resulting data achieve the accuracy stipulated for the survey class.

8.4 Data Presentation

The following information shall be shown for each spatial zone:

(a) sample size specifying the number of microphone locations in each spatial noise zone;

(b) spatial standard deviation over the entire measurement period for each type of noise zone, based on the sample population of the basic sound level measured in terms of the sound level descriptor (e.g., equivalent-continuous sound level, day–night average sound level, etc.) selected for the survey; and

(c) location of the microphone at each measurement site, illustrated graphically, or described, in sufficient detail so that the same microphone position, within a horizontal tolerance of ± 1 meter, could be reproduced again.

9 TEMPORAL SAMPLING REQUIREMENTS

9.1 General

Continuous measurements, or the sampling strategy for discontinuous measurements, shall be long enough to achieve the desired accuracy and confidence interval. Statistical accuracy of measurements may be increased only by additional *independent* information. This additional information may be acoustical data or nonacoustical data such as information concerning the operations of the various noise sources. Factors which limit statistical accuracy and confidence are weather and sound source operations. (Appendix B discusses factors which affect independence of data.)

9.2 Confidence Interval

The goal of long-term community sound measurements shall be a 95% confidence interval. (That is, one can state with 95% confidence that the true long-term average sound level lies within the stated interval.)

9.3 Accuracy Requirements

In general the precision of direct, long-term measurements can only be inferred by evaluating the statistics of the data and the assumptions as to independence of the data. There are three temporal accuracy classes for the measurement of day–night average sound level (DNL) or day–night average sound exposure (DNSE), each with a 95% confidence interval:

Class	DNL	DNSE
A	+ 2 dB − 3 dB	+ 60% − 50%
B	+ 3 dB − 10 dB	+ 100% − 90%
C	+ 5 dB − 5 dB	+ 300% − 70%

NOTE: These three classes are nominally ± 50%, ± 100%, and near worst case, respectively.

9.4 Data Dependence

The measured sound levels shall be known to be independent before measurement precision is estimated.

9.4.1 Inferred independence. Measurements of sound level may be inferred to be independent when the measurement days are specifically selected to sample across factors known to possibly result in time dependence. These factors include days of the week and seasons of the year. Consecutive daily samples shall not be inferred to be independent.

9.4.2 Tested independence. Consecutive daily samples and other data suspected of possibly being time correlated shall be tested for statistical independence. In order to test the time series of measurements, the autocorrelation for the Z-scores of this time series data shall be calculated, where the Z-score for any observation, i, of a sound level is given by:

$$\text{Z-score}_i = \frac{(\text{observation}_i - \text{sample mean})}{(\text{sample standard deviation})}.$$

The time lag is the unit of observation, ΔT, to the time series. For typical community noise measures such as day–night average sound level, the unit of observation is one day. By definition, the autocorrelation for time lag 0 is 1. The absolute magnitude of autocorrelation for all time lags greater than 0 shall be less than $2/(N)^{1/2}$, where N is the number of samples in the time series. Appendix C provides examples of this process. For any time series, the autocorrelation function, $A(\tau)$, for time lag τ is given by:

$$A(\tau) = (\Sigma L_i L_{i+\tau})/[\Sigma (L_i)^2],$$

where L_i is the sound level of the ith sound level in a series of measurements at a site.

9.4.3 Correction for nonindependent data. When data are nonindependent, the absolute magnitude of the autocorrelation for some time lags greater than 0 is greater than the criterion given in Sec. 9.4.2. For lags near to 0, the largest time lag failing to meet this criterion shall be used to calculate the dependence factor. This time lag plus 1 shall be taken as the dependence factor. For dependent data, sampling requirements calculated in Sec. 9.5 shall be multiplied by the dependence factor in order to calculate the true sampling requirements.

Lags not near 0 which fail to meet the test for independence indicate seasonal effects. For example, a strong positive autocorrelation value for a lag of 7 days indicates a weekly cycle to the data. This result indicates the need to adopt means to sample during different weeks throughout the year, or on different days throughout several weeks, or apply other means to obtain statistically independent temporal samples.

9.5 Class A Measurements

Class A measurements are the most precise; see Sec. 9.3.

9.5.1 Computation of temporal sampling requirements. Sampling requirements can be computed when the data come from a known distribution (e.g., normal or log-normal), and the data known to be independent; otherwise the method in Sec. 9.4.3 shall be used to adjust these sampling requirements. The following two sections give sampling requirements for normal and log-normal distributions of daily day–night (total) sound exposure measurements in terms of their means and standard deviations.

9.5.1.1 Normally distributed day–night sound exposure data. For normally distributed day–night sound exposure data, the number (n) of independent samples required to achieve the $\pm 50\%$ accuracy in estimating the mean of the day–night sound exposure data with a 95% confidence level is given in terms of the ratio of the sample standard deviation (σ) to the sample mean (μ):

$$n = 16(\sigma/\mu)^2, \tag{1}$$

where $\mu = (1/N)\,\Sigma_{i=1}^{N}\,\text{DNSE}_i$, the probability density for DNSE_i is $[1/\sigma(2\pi)^{1/2}]\exp\{-(1/2) \times [(\text{DNSE}_i - \mu)/\sigma]^2\}$, and N = the number of samples.

The sample distribution for day–night (total) sound exposures shall pass a test for normality such as the Kolmogorov-Smirnov test.[2–4] Significance tables can be found in Owen.[5] Appendix D provides an example test for normality using the Kolmogorov-Smirnov method.

9.5.1.2 Normally distributed day–night average sound levels. Day–night average sound levels which are normally distributed come from a distribution where the day–night (total) sound exposures are log-normally distributed.[6]

For normally distributed day–night average sound levels, the confidence interval (CI) about the mean square level (L_{ms}) can be determined.

First, the mean square day–night average sound level (L_{ms}) can be calculated directly, or it can be estimated from:

$$L_{ms} = L_{ave} + 0.115 s^2, \tag{2}$$

where L_{ave} is the mean of the sample of day–night average sound levels, and s is the standard deviation of the data sample.

Let CI_{ave} be the confidence interval for the sample of day–night average sound levels and let CI_s be the confidence interval for the standard deviation of the sample. In terms of these two confidence intervals, the confidence interval for the mean square level, CI_{msL}, is estimated by computing the total differential of Eq. (2).[7] Thus,

$$(\text{CI}_{msL})^2 = (\text{CI}_{ave})^2 + (2 \times 0.115 \times s)^2 \times (\text{CI}_s)^2. \tag{3}$$

The confidence interval for sample standard deviation, *s*, can be determined from the chi-square statistic. These confidence intervals are *not* symmetric about the standard deviation. Thus, the confidence limits for the mean square level, CI_{msl}, are not symmetric.

NOTE: The confidence limits for the mean square level are always greater than the corresponding confidence limits for the average level. These limits converge for large data sets.

Table 1 lists the "*t*" and "*k*" values that are needed for calculating the confidence intervals for the mean square level. In this table, *k* 1 is used to calculate the lower confidence limit and *k* 2 is used to calculate the upper confidence limit for the DNL sample standard deviation. So, for a sample of *n* measurements:

$$CI_{ave} = [(s \times t_{n-1})^2/n]^{1/2},$$

TABLE 1. Factors for calculating confidence levels for average and mean square values.

		90% confidence limits			95% confidence limits		
n	*f* (*n* − 1)	*t*	*k* 1	*k* 2	*t*	*k* 1	*k* 2
2	1	6.314	0.490	14.947	12.706	0.554	30.910
3	2	2.920	0.422	3.415	4.303	0.479	5.285
4	3	2.353	0.380	1.920	3.182	0.434	2.729
5	4	2.132	0.351	1.372	2.776	0.401	1.874
6	5	2.015	0.328	1.089	2.571	0.376	1.453
7	6	1.943	0.310	0.915	2.447	0.356	1.202
8	7	1.895	0.295	0.797	2.365	0.339	1.035
9	8	1.860	0.282	0.711	2.306	0.325	0.916
10	9	1.833	0.271	0.645	2.262	0.312	0.826
11	10	1.812	0.261	0.593	2.228	0.301	0.755
12	11	1.796	0.252	0.551	2.201	0.292	0.698
13	12	1.782	0.245	0.515	2.179	0.283	0.651
14	13	1.771	0.238	0.485	2.160	0.275	0.611
15	14	1.761	0.231	0.460	2.145	0.268	0.577
16	15	1.753	0.225	0.437	2.131	0.261	0.548
17	16	1.746	0.220	0.418	2.120	0.255	0.522
18	17	1.740	0.215	0.400	2.110	0.250	0.499
19	18	1.734	0.210	0.384	2.101	0.244	0.479
20	19	1.729	0.206	0.370	2.093	0.240	0.461
21	20	1.725	0.202	0.358	2.086	0.235	0.444
22	21	1.721	0.198	0.346	2.080	0.231	0.429
23	22	1.717	0.195	0.335	2.074	0.227	0.415
24	23	1.714	0.191	0.326	2.069	0.223	0.403
25	24	1.711	0.188	0.316	2.064	0.219	0.391
26	25	1.708	0.185	0.308	2.060	0.216	0.380
27	26	1.706	0.182	0.300	2.056	0.212	0.370
28	27	1.703	0.180	0.293	2.052	0.209	0.361
29	28	1.701	0.177	0.286	2.048	0.206	0.352
30	29	1.699	0.175	0.280	2.045	0.204	0.344
31	30	1.697	0.172	0.274	2.042	0.201	0.337
36	35	1.690	0.162	0.249	2.030	0.189	0.306
40	39	1.685	0.155	0.232	2.023	0.181	0.285
41	40	1.684	0.153	0.228	2.021	0.179	0.280
51	50	1.678	0.139	0.199	2.011	0.163	0.243
61	60	1.671	0.129	0.179	2.000	0.151	0.217
71	70	1.668	0.121	0.163	1.995	0.142	0.198
81	80	1.666	0.114	0.151	1.992	0.134	0.183
91	90	1.664	0.108	0.141	1.989	0.127	0.171
101	100	1.662	0.103	0.133	1.986	0.121	0.161

$$\mathrm{CI}_{s\text{-lower}} = s \times k1_{n-1},$$

$$\mathrm{CI}_{s\text{-upper}} = s \times k2_{n-1}.$$

NOTE: The $k1$ value is given by $(1 - b1)$ and the $k2$ value is given by $(b2 - 1)$, where the $b1$ and $b2$ values are given in Table 8 of Crow.[6] Table 1 also shows the degrees of freedom, f, set equal to $(n - 1)$, where n is the number of samples. These calculations hold for a single set of samples of day–night average sound level.

From Eq. (3), the equations for calculating the *two* mean square confidence limits become

$$\mathrm{CI}_{\mathrm{msL}} = s \times [(t_{n-1})^2/n + (0.05290) \times (k1_{n-1} \times s)^2]^{1/2} \quad (4)$$

for the lower limit, and

$$\mathrm{CI}_{\mathrm{msL}} = s \times [(t_{n-1})^2/n + (0.05290) \times (k2_{n-1} \times s)^2]^{1/2} \quad (5)$$

for the upper limit.

For planning purposes, the larger (upper) confidence limit is usually most meaningful. Figure 1 is a chart for estimating the number of samples required to achieve a given 95% confidence interval for the mean square level, given an estimated sample standard deviation.

Table C2 of Appendix C provides an example computation of confidence limits for a normally distributed sample of day–night average sound levels.

The DNL (log-transformed DNSE) sample distribution shall pass a test for normality as described in 9.5.1.1. Appendix C provides an example test for normality using the Kolmogorov–Smirnov method.

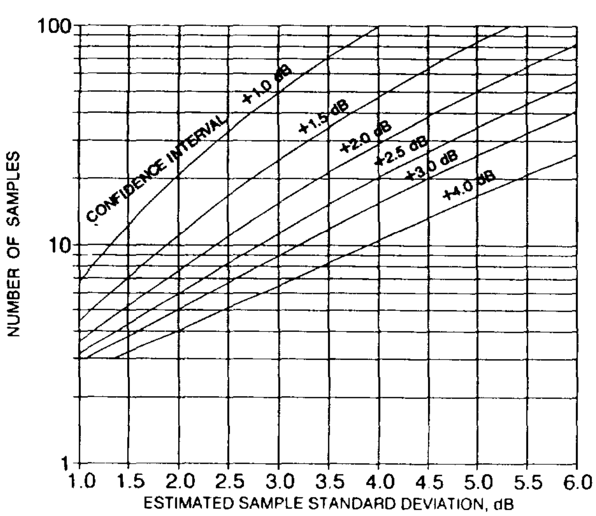

FIG. 1. Mean square day–night average sound levels. Number of samples for 95% upper confidence interval.

9.5.2 Estimation of temporal sampling requirements. Typically, the distribution describing the data is not known and statistical independence cannot be assumed. Based on analysis of community sound levels, the following guidelines apply for various situations in order to achieve Class A accuracy with a 95% confidence level:

9.5.2.1 Industrial and other primarily fixed noise sources. Measurements shall be made for four (4) distinctly different, entire days of the week. One day shall be chosen from each quarter of a year.

9.5.2.2 Highways. Measurements shall be made for four (4) distinctly different, entire days of the week including one normal Saturday or Sunday. One measurement day shall be chosen from each quarter of a year.

9.5.2.3 Residential areas with no distinct noise sources. Measurements shall be made for two (2) entire days. One measurement day shall be chosen from each half of a year or time period of interest.

9.5.2.4 Airports. One of two sample methods shall be employed.

(a) Measurements shall be made for fourteen (14) entire days. These 14 days shall include two (2) samples for each day of the week. Each measurement day shall be separated from the previous by at least eight (8) days and three (3) to four (4) measurement days shall be drawn from each quarter of a year; or,

(b) Measurements shall be made for twenty-eight (28) entire days taken seven (7) consecutive days at a time. One 7-day measurement period shall be chosen from each quarter of a year.

9.5.2.5 Military installations and other similar facilities. The temporal sampling requirements for military installations and other similar sound sources where operations change dramatically ($\pm$ 100% or more) by day, week, or quarter are as follows:

(a) Sound levels vary daily: Four (4) entire weeks, one from each quarter, are required.

(b) Sound levels vary weekly: Four (4) entire months, one from each quarter, are required.

(c) Sound levels vary seasonally: The entire quarter or time period of activity shall be monitored with the provision that whole weeks, such as every other or every third week, be monitored.

9.5.3 Approximation of sampling requirements. If one has monitored data [e.g., day–night (total) sound exposures] from a known distribution with known statistics, but the data are not independent, then analysis of existing community data indicates that the sample size shall be increased by a factor of four (4) over the sample size which would have been required if the data were independent. For example, if the distribution is normal or log-normal and the standard deviation is known, then the number of samples required is given by the values from Sec. 9.5.1.1 or Sec. 9.5.1.2 multiplied by four.

9.6 Class B Measurements

Class B measurements are less precise than Class A measurements (see Sec. 9.3). Class B measurements require half the number of data samples that are required for a corresponding Class A measurement.

9.7 Class C Measurements

Class C measurements are intended to define an upper limit to the environmental sound levels; the highest or worst case. Class C measurements should be performed only when the distance of closest approach from primary sound source(s) to the measurement site is less than 3 km (2 miles). These measurements are made for one day. The measurement site shall be downwind of the primary source(s), or under equivalent propagation conditions. The day shall be a typical, active day for operation of the sound source(s). The ground surface shall not be snow-covered. Class C measurements shall not be made for unlikely (probability less than 30%) situations such as a downwind location which is normally upwind. The "worst case" conditions are met when:

(1) the wind direction is within an angle of $\pm 45°$ of the direction connecting the source and the receiving location, with the wind blowing from source to receiver;

(2) the wind velocity is between 0.5 and 6 meters per second, when measured at a height which is between 3 and 11 m above the ground;

(3) there is a well-developed ground-based temperature inversion, such as the inversion which commonly occurs at night.

APPENDIX A: REFERENCES

[This Appendix is not a part of American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound. Part 2: Measurement of long-term, wide-area sound, ANSI S12.9-1992/Part 2 (ASA Catalog No. 105-1992), but is included for information purposes only.]

[1]Aerospace Recommended Practice (ARP) 4721, Monitoring Noise From Aircraft Operations in the Vicinity of Airports.

[2]Johnson, Norman L. and Fred D. Leone, "Statistics and Experimental Design in Engineering and the Physical Sciences," Chap. 8 (Wiley and Sons, NY, 1977).

[3]Hollander, M. *et al.*, "Non-parametric Statistical Methods," Chap. 10 (Wiley and Sons, NY, 1973).

[4]D'Agostino *et al.*, "Goodness-of-Fit Techniques," Chap. 4 (Dekker, NY, 1986).

[5]Owen, Donald B., "Handbook of Statistical Tables" (Addison-Wesley, Reading, MA, 1962).

[6]Aitchison, J. and J. A. C. Brown, "The Log-normal Distribution," Chap. 4 (University of Cambridge, U.K., 1969).

[7]Crow, E. L., *et al.*, "Statistics Manual" (Dover Publications, 1960) (republication of NAVORD Report 3369-NOTS 948).

[8]Johnson, Norman L. and Fred D. Leone, "Statistics and Experimental Design in Engineering and the Physical Sciences," Chap. 8 (Wiley and Sons, NY, 1977).

[9]Hollander, M. *et al.*, "Non-parametric Statistical Methods," Chap. 10 (Wiley and Sons, NY, 1973).

[10]D'Agostino *et al.*, "Goodness-of-Fit Techniques," Chap. 4 (Dekker, NY, 1986).

[11]Owen, Donald B., "Handbook of Statistical Tables" (Addison-Wesley, Reading, MA, 1962).

[12]Aitchison, J. and J. A. C. Brown, "The Log-normal Distribution," Chap. 4 (University of Cambridge, U.K., 1969).

APPENDIX B: DATA INDEPENDENCE OR DEPENDENCE; CONTRIBUTING FACTORS

[This Appendix is not a part of American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound. Part 2: Measurement of long term, wide-area sound, ANSI S12.9-1992/Part 2 (ASA Catalog 105-1992), but is included for information purposes only.]

B.1 Independent Data

With statistically independent data, each datum is unrelated to its neighbors in time. Each datum is related only to the underlying probability distribution describing the total data set. For example, suppose one has a continuous set of 30, daily day–night (total) sound exposure (DNSE) measurements for which one wishes to estimate the yearly average DNSE and its statistical precision. The average is the sum of the 30 exposures divided by 30. The data are independent if one has no better estimate of the DNSE on one day given a measurement of DNSE on the preceding day than one does without having measured on the preceding day. If the data meet the test of independence, then the standard deviation of the distribution can be used to calculate the statistical confidence intervals.

B.2 Dependent Data

Data samples which are too close together in time may be dependent. For example, suppose that the acoustical data are one-day measurements of DNSE, the dominant noise source is a nearby freeway, and the measurement site is downwind of the freeway on a given measurement day. At many locations in the world it is likely that the site will be downwind on the next day. Weather patterns are usually such that only samples several days or more apart are truly independent. Weather patterns may also affect the operations of the source as well as the acoustical sound propagation. For example, wind direction affects airport runway usage. This, in turn, affects the noise received in the adjacent communities. Also, the source itself may have a temporal pattern. A freeway may be busier on weekdays, a road to the beach may be busier on weekends, a factory may close on weekends, and an airport may have many extra charter flights during peak holiday periods.

B.3 Weather Effects

Weather affects the propagation of sound from source to receiver. Wind direction and its altitude profile, and the presence (or absence) of low-level temperature inversions are the primary factors affecting sound propagation over distances of as little as 100 meters (m). Relative humidity and temperature are the primary factors controlling sound absorption by the atmosphere. These factors vary with season. For example, winds may be southerly in summer and northerly in winter, temperature inversions may be common in winter and rare in summer, and relative humidity may vary with the season, being highest in spring or summer.

The variation of received community sound with weather conditions increases with increasing distance from the sound source and the spectral content of the sound source. In general, variation increases with distance and sound frequency. Typical community sound sources will vary 10 decibels (dB) at 300 m and will vary by 40 dB or more at 3 kilometers (km). Since weather is the primary factor affecting sound propagation, in the absence of other information, it is impossible to determine average sound levels within a period of time that is shorter than a characteristic time period for variation of weather conditions about their long time average. For example, if wind is the primary variable at a given site then it is impossible to accurately measure the average received sound unless one measures long enough to incorporate a good average of wind conditions or otherwise takes into account the variation of received sound with weather.

One means to avoid protracted community noise measurements is to measure the received sound under a set of carefully selected weather conditions, especially for spatially fixed sound sources. For example, one could measure the received noise from a factory specifically under downwind, upwind, and crosswind conditions. Then, using long-term weather statistics, one can predict a long-term average for the received sound. However, a conservative evaluation of environmental sound from specific sources is best obtained from downwind propagation.

B.4 Source Operational Effects

The second dominant variable affecting the received sound is temporal variation in operation of the source. For example, a factory may operate 16 hours per day, 6 days per week. If the purpose of a community noise measurement is to measure the factory noise in some community, then one need only measure during times when the factory is in operation. The average received sound is predicted from the ratio of factory operation to total time.

B.5 Combined Effects

These sound level prediction concepts based on controlled measurements can be combined. For the case of the factory cited above, one could measure the received sound when the factory was in operation during upwind, downwind, and crosswind conditions. Then one could predict the average received sound based on the actual operations of the factory and the statistical breakdown of wind conditions during the hours when the factory operates.

As temporally varying modes of source operation and as weather variables increase, the tasks of controlled measurements and prediction increase in difficulty. The alternative is direct, long-term, effectively continuous community noise measurement of the average received sound.

APPENDIX C: TESTING FOR INDEPENDENCE

[This Appendix is not a part of American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound. Part 2: Measurement of long-term, wide-area sound, ANSI S12.9-1992/Part 2 (ASA Catalog No. 105-1992), but is included for information purposes only.]

The autocorrelation of the Z-scores from a set of time series data is used to test the data for statistical independence of the time series. This appendix includes four examples of time-series data. Each example includes a table listing the data, the Z-scores and the autocorrelation calculation; a plot of the time series; and a plot of the autocorrelation. These examples all use the made-up data given in Appendix D, Table D2. Each figure includes the two lines at $\pm 2/(N)^{1/2}$ marking the criteria for independence. That is, any two data samples can be considered statistically independent when they are separated by a time lag τ for which the autocorrelation function $A(\tau)$ falls within the $\pm 2/(N)^{1/2}$ independence criteria. The four examples are:

(1) Table C1 and Fig. C1 use the data exactly in the order given in Table D2.

(2) Table C2 and Fig. C2 use the data from Table D2 shuffled by computer to be completely random.

(3) Table C3 and Fig. C3 use the data from Table D2 ordered from largest to smallest.

(4) Table C4 and Fig. C4 use the data from Table D2 alternated in order from largest to smallest.

Clearly, the first two data sets show statistical independence for any two samples separated by one or more time-lag periods (e.g., one or more days for daily sampled data).

TABLE C1. Hand-created example data.

				Autocorrelation						
	DNL	DNSE	Z-score	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 6
1	56.0	13.7	−1.611	2.60	0.14	−0.67	2.19	−2.72	0.55	−3.13
2	62.0	54.6	−0.089	0.01	−0.04	0.12	−0.15	0.03	−0.17	−0.01
3	64.0	86.5	0.419	0.18	−0.57	0.71	−0.14	0.81	0.07	−0.46
4	57.0	17.3	−1.358	1.84	−2.29	0.47	−2.64	−0.22	1.50	0.12
5	69.0	273.5	1.688	2.85	−0.58	3.28	0.28	−1.86	−0.15	−1.01
6	61.0	43.4	−0.343	0.12	−0.67	−0.06	0.38	0.03	0.20	−0.06
7	70.0	344.3	1.941	3.77	0.32	−2.14	−0.17	−1.16	0.32	−1.65
8	63.0	68.7	0.165	0.03	−0.18	−0.01	−0.10	0.03	−0.14	0.24
9	58.0	21.7	−1.104	1.22	0.10	0.66	−0.18	0.94	−1.58	0.66
10	62.0	54.6	−0.089	0.01	0.05	−0.01	0.08	−0.13	0.05	0.03
11	60.0	34.4	−0.596	0.36	−0.10	0.51	−0.86	0.36	0.20	0.51
12	63.0	68.7	0.165	0.03	−0.14	0.24	−0.10	−0.06	−0.14	0.28
13	59.0	27.4	−0.850	0.72	−1.22	0.51	0.29	0.72	−1.43	0.08
14	68.0	217.3	1.434	2.06	−0.86	−0.49	−1.22	2.42	−0.13	0.60
15	60.0	34.4	−0.596	0.36	0.20	0.51	−1.01	0.05	−0.25	0.00
16	61.0	43.4	−0.343	0.12	0.29	−0.58	0.03	−0.14	0.00	0.00
17	59.0	27.4	−0.850	0.72	−1.43	0.08	−0.36	0.00	0.00	0.00
18	69.0	273.5	1.688	2.85	−0.15	0.71	0.00	0.00	0.00	0.00
19	62.0	54.6	−0.089	0.01	−0.04	0.00	0.00	0.00	0.00	0.00
20	64.0	86.5	0.419	0.18	0.00	0.00	0.00	0.00	0.00	0.00
Mean	62.4	92.3								
STD	3.9	96.7								
Energy mean		64.3								
Column sum				20.00	−7.15	3.79	−3.68	−0.90	−1.10	−3.81
Autocorrelation				1.00	−0.36	0.19	−0.18	−0.05	−0.05	−0.19

TABLE C2. Randomized data—no correlation.

	DNL	DNSE	Z-score	Autocorrelation Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 6
1	59.0	27.4	−0.850	0.72	−0.36	0.51	0.08	−0.14	−0.14	0.72
2	64.0	86.5	0.419	0.18	−0.25	−0.04	0.07	0.07	−0.36	−0.14
3	60.0	34.4	−0.596	0.36	0.05	−0.10	−0.10	0.51	0.20	0.66
4	62.0	54.6	−0.089	0.01	−0.01	−0.01	0.08	0.03	0.10	−0.13
5	63.0	68.7	0.165	0.03	0.03	−0.14	−0.06	−0.18	0.24	0.07
6	63.0	68.7	0.165	0.03	−0.14	−0.06	−0.18	0.24	0.07	−0.01
7	59.0	27.4	−0.850	0.72	0.29	0.94	−1.22	−0.36	0.08	−1.43
8	61.0	43.4	−0.343	0.12	0.38	−0.49	−0.14	0.03	−0.58	0.20
9	58.0	21.7	−1.104	1.22	−1.58	−0.46	0.10	−1.86	0.66	0.10
10	68.0	217.3	1.434	2.06	0.60	−0.13	2.42	−0.86	−0.13	2.78
11	64.0	86.5	0.419	0.18	−0.04	0.71	−0.25	−0.04	0.81	−0.67
12	62.0	54.6	−0.089	0.01	−0.15	0.05	0.01	−0.17	0.14	0.12
13	69.0	273.5	1.688	2.85	−1.01	−0.15	3.28	−2.72	−2.29	−0.58
14	60.0	34.4	−0.596	0.36	0.05	−1.16	0.96	0.81	0.20	−1.01
15	62.0	54.6	−0.089	0.01	−0.17	0.14	0.12	0.03	−0.15	0.00
16	70.0	344.3	1.941	3.77	−3.13	−2.64	−0.67	3.28	0.00	0.00
17	56.0	13.7	−1.611	2.60	2.19	0.55	−2.72	0.00	0.00	0.00
18	57.0	17.3	−1.358	1.84	0.47	−2.29	0.00	0.00	0.00	0.00
19	61.0	43.4	−0.343	0.12	−0.58	0.00	0.00	0.00	0.00	0.00
20	69.0	273.5	1.688	2.85	0.00	0.00	0.00	0.00	0.00	0.00
Mean	62.4	92.3								
STD	3.9	96.7								
Energy mean		64.3								
Column sum				20.00	−3.36	−4.76	1.77	−1.34	−1.14	0.68
Autocorrelation				1.00	−0.17	−0.24	0.09	−0.07	−0.06	0.03

TABLE C3. Ordered data—positive correlation.

	DNL	DNSE	Z-score	Autocorrelation Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 6
1	70.0	344.3	1.941	3.77	3.28	3.28	2.78	0.81	0.81	0.32
2	69.0	273.5	1.688	2.85	2.85	2.42	0.71	0.71	0.28	0.28
3	69.0	273.5	1.688	2.85	2.42	0.71	0.71	0.28	0.28	−0.15
4	68.0	217.3	1.434	2.06	0.60	0.60	0.24	0.24	−0.13	−0.13
5	64.0	86.5	0.419	0.18	0.18	0.07	0.07	−0.04	−0.04	−0.04
6	64.0	86.5	0.419	0.18	0.07	0.07	−0.04	−0.04	−0.04	−0.14
7	63.0	68.7	0.165	0.03	0.03	−0.01	−0.01	−0.01	−0.06	−0.06
8	63.0	68.7	0.165	0.03	−0.01	−0.01	−0.01	−0.06	−0.06	−0.10
9	62.0	54.6	−0.089	0.01	0.01	0.01	0.03	0.03	0.05	0.05
10	62.0	54.6	−0.089	0.01	0.01	0.03	0.03	0.05	0.05	0.08
11	62.0	54.6	−0.089	0.01	0.03	0.03	0.05	0.05	0.08	0.08
12	61.0	43.4	−0.343	0.12	0.12	0.20	0.20	0.29	0.29	0.38
13	61.0	43.4	−0.343	0.12	0.20	0.20	0.29	0.29	0.38	0.47
14	60.0	34.4	−0.596	0.36	0.36	0.51	0.51	0.66	0.81	0.96
15	60.0	34.4	−0.596	0.36	0.51	0.51	0.66	0.81	0.96	0.00
16	59.0	27.4	−0.850	0.72	0.72	0.94	1.15	1.37	0.00	0.00
17	59.0	27.4	−0.850	0.72	0.94	1.15	1.37	0.00	0.00	0.00
18	58.0	21.7	−1.104	1.22	1.50	1.78	0.00	0.00	0.00	0.00
19	57.0	17.3	−1.358	1.84	2.19	0.00	0.00	0.00	0.00	0.00
20	56.0	13.7	−1.611	2.60	0.00	0.00	0.00	0.00	0.00	0.00
Mean	62.4	92.3								
STD	3.9	96.7								
Energy mean		64.3								
Column sum				20.00	15.98	12.47	8.73	5.45	3.68	1.99
Autocorrelation				1.00	0.80	0.62	0.44	0.27	0.18	0.10

TABLE C4. Alternated data—negative correlation.

	DNL	DNSE	Z-score	Autocorrelation Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 6
1	70.0	344.3	1.941	3.77	−3.13	3.28	−2.64	3.28	−2.14	2.78
2	56.0	13.7	−1.611	2.60	−2.72	2.19	−2.72	1.78	−2.31	1.37
3	69.0	273.5	1.688	2.85	−2.29	2.85	−1.86	2.42	−1.43	0.71
4	57.0	17.3	−1.358	1.84	−2.29	1.50	−1.95	1.15	−0.57	1.15
5	69.0	273.5	1.688	2.85	−1.86	2.42	−1.43	0.71	−1.43	0.71
6	58.0	21.7	−1.104	1.22	−1.58	0.94	−0.46	0.94	−0.46	0.66
7	68.0	217.3	1.434	2.06	−1.22	0.60	−1.22	0.60	−0.86	0.24
8	59.0	27.4	−0.850	0.72	−0.36	0.72	−0.36	0.51	−0.14	0.51
9	64.0	86.5	0.419	0.18	−0.36	0.18	−0.25	0.07	−0.25	0.07
10	59.0	27.4	−0.850	0.72	−0.36	0.51	−0.14	0.51	−0.14	0.29
11	64.0	86.5	0.419	0.18	−0.25	0.07	−0.25	0.07	−0.14	−0.04
12	60.0	34.4	−0.596	0.36	−0.10	0.36	−0.10	0.20	0.05	0.20
13	63.0	68.7	0.165	0.03	−0.10	0.03	−0.06	−0.01	−0.06	−0.01
14	60.0	34.4	−0.596	0.36	−0.10	0.20	0.05	0.20	0.05	0.05
15	63.0	68.7	0.165	0.03	−0.06	−0.01	−0.06	−0.01	−0.01	0.00
16	61.0	43.4	−0.343	0.12	0.03	0.12	0.03	0.03	0.00	0.00
17	62.0	54.6	−0.089	0.01	0.03	0.01	0.01	0.00	0.00	0.00
18	61.0	43.4	−0.343	0.12	0.03	0.03	0.00	0.00	0.00	0.00
19	62.0	54.6	−0.089	0.01	0.01	0.00	0.00	0.00	0.00	0.00
20	62.0	54.6	−0.089	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Mean	62.4	92.3								
STD	3.9	96.7								
Energy mean		64.3								
Column sum				20.00	−16.67	15.97	−13.40	12.44	−9.85	8.69
Autocorrelation				1.00	−0.83	0.80	−0.67	0.62	−0.49	0.43

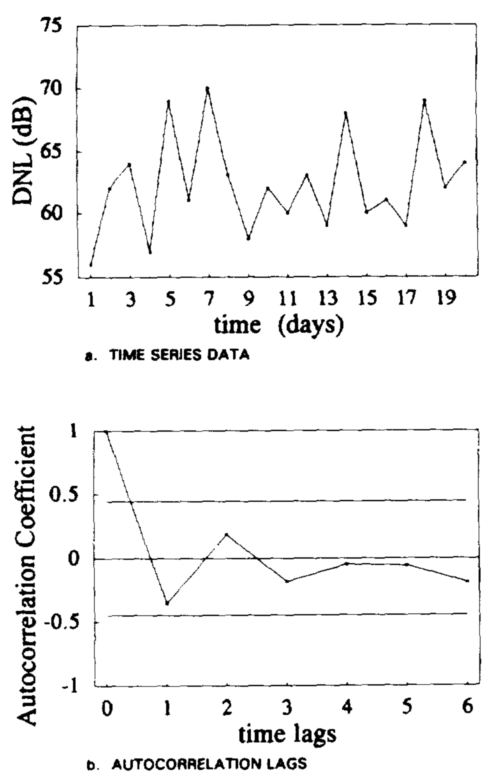

FIG. C1. Hand-created example data.

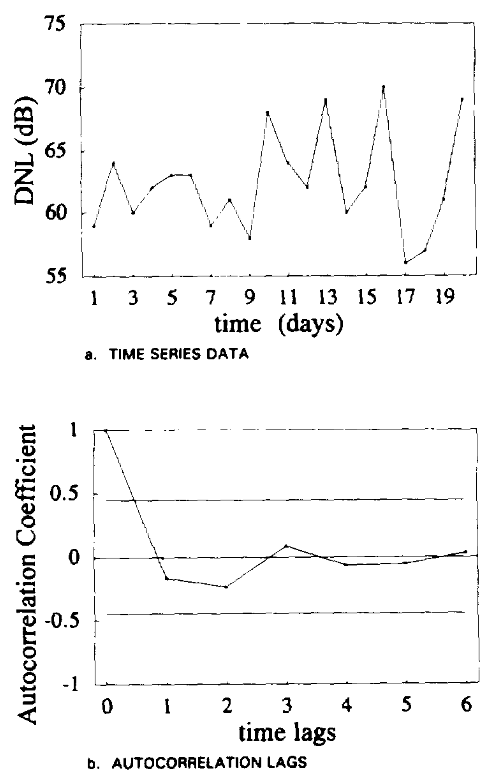

FIG. C2. Randomized data—no correlation.

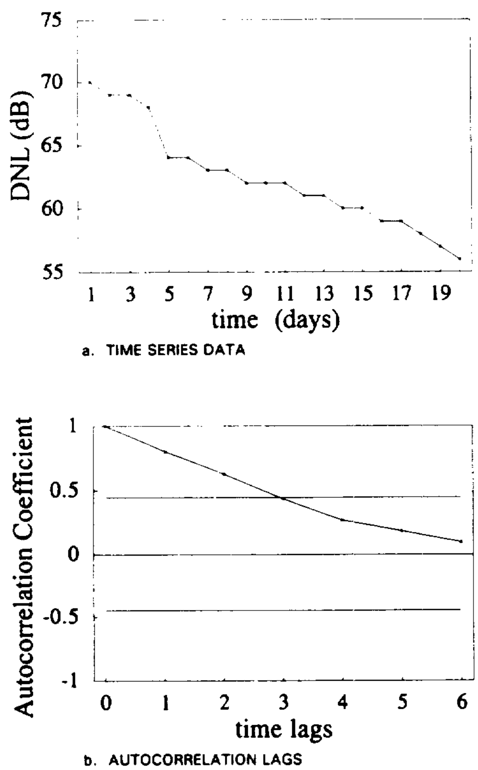

FIG. C3. Ordered data—positive correlation.

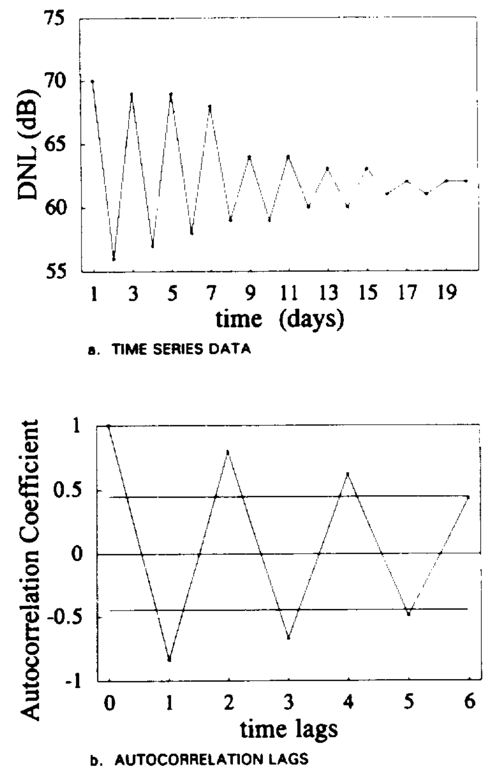

FIG. C4. Alternated data—negative correlation.

APPENDIX D: SAMPLE APPLICATION OF THE KOLMOGOROV–SMIRNOV TEST FOR NORMALITY OF DATA

[This Appendix is not a part of American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound. Part 2: Measurement of long-term, wide-area sound, ANSI S12.9-1992/Part 2 (ASA Catalog No. 105-1992), but is included for information purposes only.]

D.1 General

This Appendix contains a sample application of the Kolmogorov–Smirnov test for normality of data.[8–10] Other methods such as chi-square[1–3] or the Cramér-von Mises ω^2 (Ref. 3) may also be used to test for normality. Significance tables can be found in Owen.[11]

The example data consists of 20 DNSE values. These are log-transformed into 20 DNL, and these 20 DNL are tested for normality. In the Kolmogorov–Smirnov test, the discrete cumulative distribution is calculated and the difference between the measured cumulative frequency and the corresponding value for the theoretical cumulative normal distribution is determined at each step of the discrete measured distribution. The maximum of the absolute value of these differences is found and compared to the critical Kolmogorov–Smirnov value. This *critical value* is found from tables in many texts.[12] This value is a function of the number of samples (20 in this example) and the desired confidence (95% under the requirements of this standard). Table D1 contains these critical values for 95% confidence as a function of the number of samples.

TABLE D1. This table contains critical values for the Kolmogorov–Smirnov test as a function of the number of samples, N.

Sample size (N)	Critical value	Sample size (N)	Critical value
1	0.975	16	0.328
2	0.842	17	0.318
3	0.708	18	0.309
4	0.624	19	0.301
5	0.565	20	0.294
6	0.521	–	–
7	0.486	25	0.32
8	0.457	–	–
9	0.432	30	0.29
10	0.410	–	–
11	0.391	35	0.27
12	0.375	–	–
13	0.361	Over 35	$1.63/N^{1/2}$
14	0.349	–	–
15	0.338	–	–

TABLE D2. This table shows the 20 example DNSE values and their corresponding log-transformed DNL and includes the mean and confidence intervals for the DNL data set.

Sample number	DNSE (pascals^2 s)	DNL[1] (dB)
1	13.7	56.0
2	54.6	62.0
3	86.5	64.0
4	17.3	57.0
5	273.5	69.0
6	43.4	61.0
7	344.3	70.0
8	68.7	63.0
9	21.7	58.0
10	54.6	62.0
11	34.4	60.0
12	68.7	63.0
13	27.4	59.0
14	217.3	68.0
15	34.4	60.0
16	43.3	61.0
17	27.4	59.0
18	273.5	69.0
19	54.6	62.0
20	86.5	64.0
Mean	92.3	62.3
Calculated mean square level		64.3
Approximate mean square level[2]		64.1
Standard deviation	96.7	3.9
Confidence intervals, 95%:[3]	Upper = 2.5 dB, Lower = 2.0 dB	

[1]DNL = 10 lg(DNSE/100) + 64.6.

[2]Calculated from arithmetic mean of DNL samples and sample standard deviation using Eq. (2) from Sec. 9.5.1.2.

[3]Calculated using Eqs. (4) and (5) and Table 1 from Sec. 9.5.1.2.

D.2 Step-by-Step Analysis (see Table D3)

(1) Column 1 contains the log-transformed DNL arranged in ascending order.

(2) Column 2 contains the observed frequency which is the number of samples at or below the observed level divided by the total number of samples (20 in this example).

(3) Column 3 contains the number of standard deviations by which the sample level departs from the sample mean. This is known as the Z-score. It is calculated by:

$$\text{Z-score} = \frac{(\text{observed level} - \text{sample mean})}{(\text{sample standard deviation})}.$$

(4) Column 4 contains the theoretical frequency. This value is a function of the Z-score (column 3) and comes from any table for the cumulative normal distribution.

(5) Column 5 contains the magnitude of the absolute value of the difference between the observed frequency (column 2) and the theoretical frequency (column 4).

(6) The maximum difference in column 5 is found and listed at the bottom of the table.

D.3 Results

In this example, the maximum difference is found to be 0.186. With a sample size of 20 and a 95% confidence (significance level of 0.05), the critical Kolmogorov–Smirnov value from Table D1 is 0.294. So, in this example, we accept the hypothesis that the underlying distribution for the log-transformed data is normal, since the maximum calculated difference is less than the critical Kolmogorov–Smirnov value.

TABLE D3. This table illustrates the step-by-step analysis.

Observed values	Observed frequency	Z-score	Theoretic frequency	Frequency difference*
56	0.05	− 1.57	0.058	0.008
57	0.10	− 1.32	0.094	0.006
58	0.15	− 1.08	0.141	0.009
59, 59	0.25	− 0.83	0.205	0.045
60, 60	0.35	− 0.58	0.281	0.069
61, 61, 61	0.50	− 0.33	0.371	0.129
62, 62, 62	0.65	− 0.087	0.464	0.186
63, 63	0.75	0.161	0.567	0.133
64, 64	0.85	0.408	0.659	0.141
68	0.90	1.397	0.919	0.081
69	0.95	1.645	0.950	0.000
70	1.00	1.892	0.971	0.029
			Maximum = 0.186	

*Absolute value of difference.

OTHER ACOUSTICAL STANDARDS AVAILABLE FROM THE STANDARDS SECRETARIAT OF THE ACOUSTICAL SOCIETY OF AMERICA

- **ASA NOISE STDS INDEX 3-1985** Index to Noise Standards

S1 STANDARDS ON ACOUSTICS

- **ANSI S1.4-1983 (ASA 47)** American National Standard Specification for Sound Level Meters
- **ANSI S1.4A-1985** Amendment to S1.4-1983
- **ANSI S1.6-1984 (R 1990) (ASA 53)** American National Standard Preferred Frequencies, Frequency Levels, and Band Numbers for Acoustical Measurements
- **ANSI S1.8-1989 (ASA 84)** American National Standard Reference Quantities for Acoustical Levels
- **ANSI S1.10-1966 (R 1986)** American National Standard Method for the Calibration of Microphones
- **ANSI S1.11-1986 (ASA 65)** American National Standard Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters
- **ANSI S1.12-1967 (R 1986)** American National Standard Specification for Laboratory Standard Microphones
- **ANSI S1.13-1971 (R 1986)** American National Standard Methods for the Measurement of Sound Pressure Levels
- **ANSI S1.20-1988 (ASA 75)** American National Standard Procedures for Calibration of Underwater Electroacoustic Transducers
- **ANSI S1.22-1992 (ASA 100)** American National Standard Scales and Sizes for Frequency Characteristics and Polar Diagrams in Acoustics
- **ANSI S1.25-1991 (ASA 98)** American National Standard Specification for Personal Noise Dosimeters (Revision of ANSI S1.25-1978)
- **ANSI S1.26-1978 (R 1989) (ASA 23)** American National Standard Method for the Calculation of the Absorption of Sound by the Atmosphere
- **ANSI S1.40-1984 (R 1990) (ASA 40)** American National Standard Specification for Acoustical Calibrators
- **ANSI S1.42-1986 (R 1992) (ASA 64)** American National Standard Design Response of Weighting Networks for Acoustical Measurements

S2 STANDARDS ON MECHANICAL SHOCK AND VIBRATION

- **ANSI S2.2-1959 (R 1990)** American National Standard Methods for the Calibration of Shock and Vibration Pickups
- **ANSI S2.3-1964 (R 1990)** American National Standard Specifications for a High-Impact Shock Machine for Electronic Devices
- **ANSI S2.4-1976 (R 1990) (ASA 8)** American National Standard Method for Specifying the Characteristics of Auxiliary Analog Equipment for Shock and Vibration Measurements
- **ANSI S2.5-1962 (R 1990)** American National Standard Recommendations for Specifying the Performance of Vibration Machines
- **ANSI S2.7-1982 (R 1986) (ASA 42)** American National Standard Balancing Terminology
- **ANSI S2.8-1972 (R 1990)** American National Standard for Describing the Characteristics of Resilient Mountings
- **ANSI S2.9-1976 (R 1990) (ASA 6)** American National Standard Nomenclature for Specifying Damping Properties of Materials
- **ANSI S2.10-1971 (R 1990)** American National Standard Methods for Analysis and Presentation of Shock and Vibration Data
- **ANSI S2.11-1969 (R 1986)** American National Standard for the Selection of Calibrations and Tests for Electrical Transducers used for Measuring Shock and Vibration
- **ANSI S2.14-1973 (R 1986)** American National Standard for Specifying the Performance of Shock Machines
- **ANSI S2.15-1972 (R 1986)** American National Standard Specification for the Design, Construction, and Operation of Class HI (High-Impact) Shock-Testing Machine for Lightweight Equipment
- **ANSI S2.17-1980 (R 1986) (ASA 24)** American National Standard Techniques of Machinery Vibration Measurement
- **ANSI S2.19-1989 (ASA 86)** American National Standard Mechanical Vibration–Balance Quality Requirements of Rigid Rotors, Part 1: Determination of Permissible Residual Unbalance
- **ANSI S2.20-1983 (R 1989) (ASA 20)** American National Standard for Estimating Airblast Characteristics for Single Point Explosions in Air, With a Guide to Evaluation of Atmospheric Propagation and Effects
- **ANSI S2.31-1979 (R 1986) (ASA 31)** American National Standard Method for the Experimental Determination of Mechanical Mobility. Part I: Basic Definitions and Transducers
- **ANSI S2.32-1982 (R 1990) (ASA 32)** American National Standard Methods for the Experimental Determination of Mechanical Mobility. Part II: Measurements Using Single-Point Translation Excitation
- **ANSI S2.34-1984 (R 1990) (ASA 34)** American National Standard Guide to the Experimental Determination of Rotation Mobility Properties and the Complete Mobility Matrix
- **ANSI S2.38-1982 (R 1990) (ASA 44)** American National Standard Field Balancing Equipment—Description and Evaluation
- **ANSI S2.40-1984 (R 1990) (ASA 50)** American National Standard Mechanical Vibration of Rotating and Reciprocating Machinery—Requirements for Instruments for Measuring Vibration Severity
- **ANSI S2.41-1985 (R 1990) (ASA 56)** American National Standard Mechanical Vibration of Large Rotating Machines With Speed Range from 10 to 200 rev/s—Measurement and Evaluation of Vibration Severity *in situ*
- **ANSI S2.42-1982 (R 1990) (ASA 46)** American National Standard Procedures for Balancing Flexible Rotors
- **ANSI S2.43-1984 (R 1990) (ASA 54)** American National Standard Criteria for Evaluating Flexible Rotor Balance
- **ANSI S2.45-1983 (R 1990) (ASA 51)** American National Standard Electrodynamic Test Equipment for Generating Vibration—Methods of Describing Equipment Characteristics
- **ANSI S2.46-1989 (ASA 82)** American National Standard Characteristics to be Specified for Seismic Transducers
- **ANSI S2.47-1990 (ASA 95)** American National Standard Vibration of Buildings—Guidelines for the Measurement of Vibrations and Evaluation of Their Effects on Buildings
- **ANSI S2.58-1983 (R 1990) (ASA 52)** American National Standard Auxiliary Tables for Vibration Generators—Methods of Describing Equipment Characteristics
- **ANSI S2.60-1987 (ASA 68)** American National Standard Balancing Machines—Enclosures and Other Safety Measures
- **ANSI S2.61-1989 (ASA 78)** American National Standard Guide to the Mechanical Mounting of Accelerometers
- **ANSI Z24.21-1957 (R 1989)** American National Standard Method for Specifying the Characteristics of Shock and Vibration Measurement

S3 STANDARDS ON BIOACOUSTICS

• **ANSI S3.1-1991 (ASA 99)** American National Standard Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms

• **ANSI S3.2-1989 (ASA 85)** American National Standard Method for Measuring the Intelligibility of Speech Over Communication Systems

• **ANSI S3.3-1960 (R 1990)** American National Standard Methods for Measurement of Electroacoustical Characteristics of Hearing Aids

• **ANSI S3.4-1980 (R 1992) (ASA 37)** American National Standard Procedure for the Computation of Loudness of Noise

• **ANSI S3.5-1969 (R 1986)** American National Standard Methods for the Calculation of the Articulation Index

• **ANSI S3.6-1989 (ASA 81)** American National Standard Specification for Audiometers

• **ANSI S3.7-1973 (R 1986)** American National Standard Method for Coupler Calibration of Earphones

• **ANSI S3.13-1987 (ASA 74)** American National Standard Mechanical Coupler For Measurement of Bone Vibrators

• **ANSI S3.14-1977 (R 1986) (ASA 21)** American National Standard for Rating Noise with Respect to Speech Interference

• **ANSI S3.18-1979 (R 1986) (ASA 38)** American National Standard Guide for the Evaluation of Human Exposure to Whole-Body Vibration

• **ANSI S3.19-1974 (R 1990) (ASA 1)** American National Standard Method for the Measurement of Real-Ear Protection of Hearing Protectors and Physical Attenuation of Earmuffs

• **ANSI S3.20-1973 (R 1986)** American National Standard Psychoacoustical Terminology

• **ANSI S3.21-1978 (R 1992) (ASA 19)** American National Standard Method for Manual Pure-Tone Threshold Audiometry

• **ANSI S3.22-1987 (ASA 70)** American National Standard Specification of Hearing Aid Characteristics

• **ANSI S3.25-1989 (ASA 80)**American National Standard For an Occluded Ear Simulator

• **ANSI S3.26-1981 (R 1990) (ASA 41)** American National Standard Reference Equivalent Threshold Force Levels for Audiometric Bone Vibrators

• **DRAFT ANSI S3.28-1986 (ASA 66)** Draft American National Standard Methods for the Evaluation of the Potential Effect on Human Hearing of Sounds with Peak A-Weighted Sound Pressure Levels Above 120 Decibels and Peak C-Weighted Sound Pressure Levels Below 140 Decibels

• **ANSI S3.29-1983 (R 1990) (ASA 48)** American National Standard Guide to the Evaluation of Human Exposure to Vibration in Buildings

• **ANSI S3.32-1982 (R 1990) (ASA 43)** American National Standard Mechanical Vibration and Shock Affecting Man—Vocabulary

• **ANSI S3.34-1986 (R 1992) (ASA 67)** American National Standard Guide for the Measurement and Evaluation of Human Exposure to Vibration Transmitted to the Hand

• **ANSI S3.35-1985 (R 1990) (ASA 59)** American National Standard Method of Measurement of Performance Characteristics of Hearing Aids Under Stimulated *in-situ* Working Conditions

• **ANSI S3.36-1985 (R 1990) (ASA 58)** American National Standard Specification for a Manikin for Simulated *in situ* Airborne Acoustic Measurements

• **ANSI S3.37-1987 (R 1992) (ASA 69)** American National Standard Preferred Earhook Nozzle Thread for Postauricular Hearing Aids

• **ANSI S3.39-1987 (ASA 71)** American National Standard Specifications for Instruments to Measure Aural Acoustic Impedance and Admittance (Aural Acoustic Immittance)

• **ANSI S3.40-1989 (ASA 79)** American National Standard Guide for the Measurement and Evaluation of Gloves Which are Used to Reduce Exposure to Vibration Transmitted to the Hand

• **ANSI S3.41-1990 (ASA 96)** American National Standard Audible Emergency Evacuation Signal

• **ANSI S3.42-1992 (ASA 103)** American National Standard Testing Hearing Aids with a Broad-Band Noise Signal

• **ANSI S3.43-1992 (ASA 102)** American National Standard Standard Reference Zero for the Calibration of Pure-Tone Bone-Conduction Audiometers

S12 STANDARDS ON NOISE

• **ANSI S12.1-1983 (R 1990) (ASA 49)** American National Standard Guidelines for the Preparation of Standard Procedures for the Determination of Noise Emission from Sources

• **ANSI S12.3-1985 (R 1990) (ASA 57)** American National Standard Statistical Methods for Determining and Verifying Stated Noise Emission Values of Machinery and Equipment

• **ANSI S12.4-1986 (R 1993) (ASA 63)** American National Standard Method for Assessment of High-Energy Impulsive Sounds with Respect to Residential Communities

• **ANSI S12.5-1985 (R 1990) (ASA 87)** American National Standard Requirements for the Performance and Calibration of Reference Sound Sources

• **ANSI S12.6-1984 (R 1990) (ASA 55)** American National Standard Method for the Measurement of the Real-Ear Attenuation of Hearing Protectors

• **ANSI S12.7-1986 (R 1993) (ASA 62)** American National Standard Methods for Measurements of Impulse Noise

• **ANSI S12.8-1987 (ASA 73)** American National Standard Methods for Determination of Insertion Loss of Outdoor Noise Barriers

• **ANSI S12.9-1988 (R 1993) (ASA 76)** American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound. Part 1

• **ANSI S12.9-1992/Part 2 (ASA 105)** American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound. Part 2

• **ANSI S12.10-1985 (R 1990) (ASA 61)** American National Standard Methods for the Measurement and Designation of Noise Emitted by Computer and Business Equipment (Revision of ANSI S1.29-1979)

• **ANSI S12.11-1987 (R 1993) (ASA 72)** American National Standard Methods for the Measurement of Noise Emitted by Small Air-Moving Devices

• **ANSI S12.12-1992 (ASA 104)** American National Standard Engineering Method for the Determination of Sound Power Levels of Noise Sources Using Sound Intensity

• **DRAFT ANSI S12.13-1991 (ASA 97)** Draft American National Standard Evaluating the Effectiveness of Hearing Conservation Programs

• **ANSI S12.14-1992 (ASA 101)** American National Standard Methods for the Field Measurement of the Sound Output of Audible Public Warning Devices Installed at Fixed Locations Outdoors

• **ANSI S12.15-1992 (ASA 106)** American National Standard for Acoustics—Portable Electric Power Tools, Stationary and Fixed Electric Tools, and Gardening Appliances—Measurement of Sound Emitted

• **ANSI S12.16-1992 (ASA 107)** American National Standard Guidelines for the Specification of Noise of New Machinery

• **ANSI S12.23-1989 (ASA 83)** American National Standard Method for the Designation of Sound Power Emitted by Machinery and Equipment

- **ANSI S12.30-1990 (ASA 94)** American National Standard Guidelines for the Use of Sound Power Standards and for the Preparation of Noise Test Codes (Revision of ANSI S1.30-1979)
- **ANSI S12.31-1990 (ASA 93)** American National Standard Precision Methods for the Determination of Sound Power Levels of Broad-Band Noise Sources in Reverberation Rooms (Revision of ANSI S1.31-1980)
- **ANSI S12.32-1990 (ASA 92)** American National Standard Precision Methods for the Determination of Sound Power Levels of Discrete-Frequency and Narrow-Band Noise Sources in Reverberation Rooms (Revision of ANSI S1.32-1980)
- **ANSI S12.33-1990 (ASA 91)** American National Standard Engineering Methods for the Determination of Sound Power Levels of Noise Sources in a Special Reverberation Test Room (Revision of ANSI S1.33-1982)
- **ANSI S12.34-1988 (R 1993) (ASA 77)** American National Standard Engineering Methods for the Determination of Sound Power Levels of Noise Sources for Essentially Free-Field Conditions over a Reflecting Plane (Revision of ANSI S1.34-1980)
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- **ANSI S12.36-1990 (ASA 89)** American National Standard Survey Methods for the Determination of Sound Power Levels of Noise Sources (Revision of ANSI S1.36-1979)
- **ANSI S12.40-1990 (ASA 88)** American National Standard Sound Level Descriptors for Determination of Compatible Land Use (Revision of ANSI S3.23-1980)

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