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Standard Guide for Preparing a Measurement Plan for Conducting Outdoor Sound Measurements[1]

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INTRODUCTION

This is one of a series of standards on the measurement and evaluation of community noise. Others in the series include Guide E 1014 for Measurement of Outdoor A-Weighted Sound Levels, which covers manual measurement, using a simple meter, and analysis of the resulting data, and Test Method E 1503 for Conducting Outdoor Sound Measurements Using a Digital Statistical Analysis System. Also under consideration or in preparation are: a standard guide for the selection of environmental noise metrics and criteria, a standard guide for determining the validity and significance of data, and a standard guide for measuring sound received from a nearby discrete fixed sound source.

1. Scope

1.1 This guide covers the preparation of a formal plan for measurement of outdoor sound levels. A documented, detailed plan is highly desirable and useful for major environmental noise studies requiring measurements at several locations over a long period. This guide is intended primarily for use in such cases. Many simple measurements can be made without extensive prior planning or documentation. It is recommended that persons or organizations routinely performing such measurements draft and use a brief generic plan based on, but not referencing, this guide.

NOTE 1—The extent of planning and plan documentation should be consistent with the budget and needs of the project. In a large measurement program it is possible that use of a formal measurement plan could result in cost savings greater than the cost of preparing the plan. A formal documented plan can be prepared for even the simplest measurement. However, on a small project, the cost of preparation of a formal plan may not be cost effective. In such cases, plan documentation could be limited to inclusion in the final report.

1.1.1 This guide addresses the following aspects of outdoor sound level measurements:

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Defining the Scope of the Measurement	5.1
Selecting the Appropriate Survey Class	5.1.1
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Specification of the following:	
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1.1.2 Test Method E 1503 for Conducting Outdoor Sound Measurements Using a Digital Statistical Analysis System addresses listed aspects of outdoor sound level measurements for situations that are normally encountered. Many other formal and informal practices also address most of these issues. However, there is sometimes a need to depart from the normal methods in order to accommodate a special situation or a regulatory requirement. This guide provides options that are technically correct for specific situations, and provides the information needed for selecting appropriate options.

1.1.3 This guide may be used when planning a program for obtaining either a single measurement set of sound level data or multiple sets of data, as well as related supporting data.

1.2 Measurements that may be planned using this guide include, but are not limited, to the following:

1.2.1 Characterization of the acoustical environment of a site.

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1.2.2 Characterization of the sound emissions of a specific sound source that exhibits a temporal variation in sound output.

1.2.3 Measurement of low-frequency sound (infra-sound) is included because it is sometimes implicated in driving structural vibration that translates to audible interior sound.

1.2.4 Measurement of impulsive sound and sound with significant tonal content.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 634 Terminology Relating to Environmental Acoustics[2]

E 1014 Guide for Measurement of Outdoor A-Weighted Sound Levels[2]

E 1503 Test Method for Conducting Outdoor Sound Measurements Using a Digital Statistical Analysis System[2]

E 1686 Guide for Selection of Environmental Noise Measurements and Criteria[2]

2.2 *ANSI Standards:*[3]

S1.4 Specification for Sound Level Meters

S1.11 Octave-band and Fractional Octave-band Analog and Digital Filters, Specifications for

S1.13 Methods for the Measurement of Sound Pressure Levels

S1.40 Specification for Acoustical (Microphone) Calibrators

S12.1 American National Standard Guidelines for the Preparation of Standard Procedures for the Determination of Noise Emission from Sources

S12.7 American National Standard Methods for Measurements of Impulse Noise

S12.9 American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Parts 1, 2, and 3

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

3. Terminology

3.1 For definitions of terms used in this guide, see Terminology C 634.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *barrier*—any obstacle, in (or near) the lines of sight between the microphone and potential sound sources, that could block, or interfere with, the direct passage of sound from potential sound sources to a receiver or a measurement location.

3.2.2 *dummy microphone*—a microphone cartridge substitute that has electrical characteristics identical to a functional microphone but that has extremely low sensitivity to incident acoustic energy. (Used instead of a functional microphone when evaluating the internal noise of an acoustic measuring system.)

3.2.3 *exceedance level*—See *percentile level*.

3.2.4 *impulse sound*—a brief, intrusive sound, such as that associated with a tire blowout, operation of a power press, or the discharge of a firearm. One definition of an impulse is an event having a rise time not more than 35 ms to peak, and a duration of not more than 500 ms to 20 dB below peak. Impulse sound also includes repetitive events occurring at rates of 20 or less per second. When the repetition rate falls between 10 and 20 per second, the perception could be that of a steady tone, and it would be measured by a sound level meter as such. (See ANSI S1.13.)

3.2.5 *interference, n*—any activity, situation or event, near the measurement location, that could produce anomalous measurement results, or that could produce data that are not representative in the context of the measurement objectives. Interferences fall into two categories: those that produce sound and those that affect the propagation of sound or the measurement process, or both. Examples of the former include air turbulence generated by the wind at, or near the microphone, and people, animals, atmospheric phenomena, or machinery making sounds in the vicinity of the microphone. Examples of path interferences are temporary surfaces, objects, or atmospheric conditions that alter the normal sound propagation path. An example of interference that affects the measurement process is an internal self noise (in the measurement system) that corresponds to a sound level that will affect the measurement results. See Annex A1 for additional details and precautions.

3.2.6 *maximum level*—the highest meter reading using the frequency weighting and time weighting required by the measurement procedure or plan.

3.2.7 *measurement plan*—a document prepared by or for the organization or individual responsible for performing the measurement, giving the purpose and objectives of the measurements and stating requirements unique and specific to the objectives. These requirements address, for example, methods of selecting measurement times and locations, number and length of measurement sets, and directions on actions to be taken in case of major changes in environment during a measurement session.

3.2.8 *measurement set*—the set of acoustical and related data obtained at a single measurement location during a specific uninterrupted time period. The time period for a measurement set is flexible but should be based on the purpose of the measurement and specified in the measurement plan. If the purpose of the measurements is to document the sound for a specific source operating condition or propagation condition, a measurement set should not extend beyond the time period in which conditions affecting sound generation or propagation remain reasonably constant. If data analysis is performed by the measuring instrument during the measurement period, the

[2] *Annual Book of ASTM Standards*, Vol 04.06.

[3] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

analysis results are considered part of the measurement set. The aggregate of measurement sets comprises the data set for the overall study.

3.2.8.1 *Discussion*—If more than one combination of conditions exists, the investigator may want to perform separate measurement sets, one at each set of conditions.

3.2.9 *statistical sound level*—a result of statistical analysis of data in a measurement set. Three representative types of statistical sound level that may be derived from either weighted or unweighted sound levels, or from fractional octave bands of sound are the following:

3.2.10 *time-average sound level*—the average sound level measured over a length of time, also known as equivalent sound level (symbol L_T or L_{eq}). The length of time must be specified when presenting the results. For unweighted sound pressure levels and fractional octave bands," time average sound pressure level" is the correct term, and ''equivalent sound pressure level" is also used. See the note under "average sound pressure level" in Terminology C 634.

3.2.11 *percentile level*—the sound level exceeded a specific (x) percent of the time in a measurement set (symbol L_x). (Sometimes called "*exceedance level*.")

3.2.12 *tonal sound*—the presence in broad-band sound of one or more simple tones (single frequencies) or complex tones (multiple frequencies or harmonics) that create a sensation of pitch in the perceived sound, and thus can be easily detected by a listener.

4. Significance and Use

4.1 This guide deals with methods and techniques that are well defined and that are understood by a trained acoustical professional. The guide has been prepared to provide both an outline for a measurement plan and guidance in selecting procedures that are appropriate for the type and purpose of the measurements to be performed. Use of the guidelines provided will produce measurement results that are reproducible and can be documented, that are consistent with requirements of government and industry, and that can be validated using information gathered and documented in the course of the measurement program.

4.2 This guide is intended to be used in preparing a measurement plan to be agreed on by the parties having a contractual interest, and, if appropriate, the regulatory or enforcement body having jurisdiction. The plan shall reference this guide. The plan may deviate from this guide providing any changes or additions, and the rationale therefore, are clearly stated in the report of any measurement referencing this guide. This guide shall not be referenced if it is not used in preparing the plan, if the detailed measurement plan is not prepared in advance of performing the measurements, or if the plan has any major inconsistencies with the guide or minor inconsistencies are not explained.

4.3 There are numerous situations for which outdoor sound level data are required. These include, but are not limited to, the following:

4.3.1 *Documentation of Sound Levels Before the Introduction of a New Sound Source*. (For example, assessment of the noise impact caused by a proposed facility and associated activities.)

4.3.2 *Comparison of Sound Levels With and Without a Specific Source Operating*, that is, assessment of the impact potential of an existing source.

4.3.3 *Comparison of Sound Levels with Criteria or Regulatory Limits*. (For example, indication of compliance with criteria for speech interference, community annoyance, building vibration, or compliance with mandated limits.) Measurements for evaluating hearing damage potential are excluded from the scope of this guide.

NOTE 2—Measurement results obtained using a plan developed according to this guide can be used in establishing compliance when the measured data are below a specified limit, or conversely, establishing noncompliance when any of the data are above a specified limit.

4.3.4 *Noise Impact Assessment and Mitigation*. A common application of data from acoustical characterization of a location or area is in modeling the effect of a projected activity on the acoustic environment and modeling the effect of noise impact mitigation plans. Because of the costs associated with noise control, especially in the case of retrofit controls, it is important that the effect of the baseline sound level be accurately assessed. Inaccurate baseline sound data can lead to over (or under) specification of mitigation measures, or to the need to add additional noise control after the fact.

4.3.5 *Monitoring the Effectiveness of a Noise Impact Mitigation Plan*.

4.3.6 *Comparison of Statistical Sound Level Data with Appropriate Criteria*.

4.3.7 *Derivation of Loudness Levels*, provided the necessary requirements regarding sample duration and signal bandwidth are observed in collecting the data. It is recommended that a specialist in the area of loudness evaluation be consulted in preparing a plan for measurements intended to produce data that will be used for this purpose.

4.4 This guide provides procedures that will work well for alternative measurement systems, ranging from a basic standard sound level meter to a sophisticated sound analysis system that incorporates digital circuits for instrument control, sampling, processing, and storing sound level data.

4.5 This guide provides (*1*) standard formats for documenting conditions under which the measurements are performed, and for reporting the results, and (*2*) procedures for making and documenting the physical observations necessary to qualify the measurements.

4.6 This guide can be used by individuals, regulatory agencies, or others in planning a program to collect acoustical data for many situations. The guide provides for ensuring data are collected according to procedures that are consistent with specified data requirements. The guide also identifies requisite capabilities of the equipment and equipment operational options.

4.7 The user is cautioned that there are many factors that can strongly influence the results obtained during measurement of outdoor sound levels and that this guide is not intended to be a substitute for the experience and judgment of experts in the field of acoustics. The guide is intended for use by people who are familiar with data requirements, who are experienced in the

measurement and analysis of outdoor sound, and who are thoroughly familiar with the use of the equipment and techniques involved.

4.8 This guide is intended only to provide an appropriate measurement procedure and, as such, does not address the methods of comparison of the acquired data with specific criteria. No procedures are provided within this guide for separating the influences of two or more simultaneously measured sounds.

4.9 The final report of work performed using a measurement plan developed using this guide shall reference the following:

4.9.1 The measurement plan and

4.9.2 This guide, with a statement of any exceptions to its use.

5. Required Sections

5.1 From this point on, the guide is presented as the outline for, and in the format of, a typical noise measurement plan. Included in the outline are mandatory sections, with guidance for preparation of appropriate text. Also included are optional sections and guidance for their use. Each section or subsection with conditional requirements shall be considered mandatory if the conditions of the requirement apply.

NOTE 3—The following section numbering for this guide continues as subsections of Section 5. The recommended numbering format for a plan uses corresponding Guide section numbers with the "5." redacted. As an option, when Guide subsections that are not mandatory are not included in the plan, the appropriate section number may be included in the plan followed by the parenthetical statement, "This section (subsection) not applicable." Use of keywords in a measurement plan is not mandatory but is recommended. Keywords would follow 10.6, and thus would be Section 11.

5.1.1 *Scope of Measurement (Mandatory)*—A clear statement of the scope of the measurement shall be prepared and agreed upon by the following parties prior to planning outdoor noise measurements: (*1*) All parties having a contractual interest in the measurements, and (*2*) State, local, or federal government officials having regulatory authority relative to sound levels (if applicable). The statement of the scope shall be formatted to provide an appropriate opening statement for the measurement plan. The following basic information shall be contained in the scope:

5.1.1.1 *Identification of Client*—The name and address of the organization or person for whom the measurements are to be made.

5.1.1.2 *Reason for Measurements*—The reason for performing the measurements, carefully described in a way that provides guidance in defining the measurement process.

5.1.1.3 *Type of Analysis Required*—The type of analysis planned for the data obtained.

5.1.1.4 *General Location*—Describe the geographic location of the measurements, for example, the area or political subdivision that encompasses all of the measurement locations. Examples of the location would be a specific named subdivision or platted area, a city, township, county, or state.

5.1.1.5 *Oversight Responsibility*—Give the names and addresses of organizations or persons, if any, having responsibility for oversight or monitoring of the measurement program.

5.1.1.6 *Property Owners*—Give the names and addresses of persons or organizations controlling access to property on which measurements are to be made. Procedures for communicating with property owners shall be summarized here. Details may be communicated separately from the plan if appropriate.

NOTE 4—In cases involving need to perform measurements on private property the plan should indicate the type of arrangement that has been made with property owners for access.

5.1.1.7 *Regulatory Information*—If the measurement is required by, or results of the measurements will be reviewed by, a regulatory agency, see Appendix X6 for recommendations relative to inclusion of regulatory information.

5.1.1.8 *Time Period Covered*—Describe the time period over which the measurements are to be made. Include any specific requirements to perform measurements while specific activities are in progress, or when certain atmospheric conditions prevail.

NOTE 5—Measurement time period requirements are discussed in detail in ANSI S12.9.

5.1.2 *Survey Class*—Select one of the following survey classes for the measurements:

5.1.2.1 Class A, defined in ANSI S12.9 as a sound-level survey designed to achieve a spatial accuracy of ±3 dB with a confidence interval of 95 %.

5.1.2.2 Class B, defined in the referenced ANSI document as designed to achieve a spatial accuracy of ±5 dB with a confidence interval of 95 %.

5.1.2.3 Class C, defined in the referenced ANSI document as designed to define the upper limit, highest level, or worst case for environmental sounds.

5.1.2.4 *Precision and Accuracy*—State the precision and accuracy objectives of the measurements.

5.2 *Attended/Unattended Measurements*—It is strongly recommended that there be agreement between the performing organization, the client, and representatives of cognizant regulatory bodies, regarding the necessity of having a qualified person in attendance during all sound level measurements. The plan shall state the rationale for the decision. See Annex A2 for guidance.

NOTE 6—An exception would be a measurement involving only the determination of the sound level exceeded 90 percent of the time (L_{90}), in this case monitoring is less critical because the analysis process strips away most of the interference related to spurious sound sources.

5.2.1 *Manually Recorded Data*—Measurements that involve manually recorded data shall have an observer present. In this case, 5.2 shall state that an appropriately trained observer, as defined in 5.3, shall be present to read and record data.

5.2.2 *Automatically Recorded Data*—For measurements for which sound level data are automatically recorded at regular intervals, 5.2 shall contain the following information:

5.2.2.1 A statement that the measurements will be attended or unattended, as the case may be. Annex A2 shall be followed in making this determination.

5.2.2.2 A list of the names of the people, and their organizations, involved in determining whether the measurements are to be attended or unattended.

5.2.3 In the case of unattended measurements, 5.2 shall state that a qualified observer, as defined in 5.3, shall be present at least part of the time during some of the measurements.

5.3 *Statement of Operator Qualifications*—Mandatory if measurement results will be used in connection with a permit application or formal environmental assessment. The plan shall include a statement regarding the requirements for qualifying an operator to set up and operate the measurement system and to measure and record supporting data. This requirement shall apply whether the measurements are attended or unattended.

5.3.1 *Qualifications and Training*—The measurement plan shall either incorporate the text of Annex A3 or shall state the extent to which the responsible person and the equipment operator(s) meet the requirements of Annex A3.

5.4 *Selection of Measurement Locations*—This paragraph, together with Annex A4 and Appendix X1 provides a guide for selecting measurement locations for use in characterizing the acoustic environment of a point, zone, district, or enclave in a manner that ensures a degree of spatial resolution necessary to adequately, and appropriately, characterize the acoustic environment of an area. (See also ANSI S12.9, Parts 2 and 3.)

5.4.1 The sound level at any point outdoors is a combination of sounds from nearby and distant sound sources. As each source varies in sound emission or distance, or as sound propagation characteristics of the area change, the combined sound level at any point changes. The amount of change in the level will depend on the relative contribution of the source involved in the change. Selection of measurement locations shall take these factors into consideration. The locations shall be selected to:

5.4.1.1 Be representative of the area or location to be studied,

5.4.1.2 Not be influenced by the interferences described in Annex A1, and

5.4.1.3 Allow effective use of the measurement resources available, particularly time and trained personnel.

5.4.2 *Documentation of Study Area*—The measurement plan shall include a map of the study area. The map shall show potential noise sources and receptors, and identify areas where the human population density exceeds 240 per km^2 (600 per square mile). The map should be drawn to a standard scale, such as 1:10 000 in which 1 cm represents 100 m (1:7200 in which 1 in. = 600 ft) for large areas, or 1:1000 in which 1 cm represents 10 m (1:720 in which 1 in. represents 60 ft) for smaller areas. As potential measurement locations are selected they shall be identified on the map by appropriate code numbers or letters. The map should be chosen, or designed, to aid in the selection of measurement locations as well as guide the measurement crew during the measurement program.

NOTE 7—See Appendix X2 for information on USGS topographic maps.

5.4.3 Select measurement locations using the following three-step process:

5.4.3.1 Using Annex A4, establish the extent of the study area and identify points within the study area at which measurements are needed.

5.4.3.2 Eliminate redundant points as outlined in X1.4.

5.4.3.3 Using Annex A1, evaluate the potential for interferences at each location. If necessary, adjust the location to avoid, or minimize, the interference.

5.5 *Schedule and Duration of Measurements*—This section provides guidelines for establishing a sampling sequence for use in preparing a plan for outdoor sound level measurements that will provide the degree of temporal resolution necessary to adequately characterize the acoustical environment of a point or area. For situations that do not require a long-term assessment it may not be necessary to make more than a single measurement, however, if the measurement is being made for any reason other than to determine the sound level at a specific time, it is recommended that the user consider the potential for time-dependent variations in level as discussed below.

NOTE 8—ANSI S12.9, Parts 2 and 3 provide guidance in setting up a measurement schedule.

5.5.1 *Temporal Changes* in sound level are often cyclic. Hourly cycles are normally based on activity patterns of the inhabitants of a community. The same is true of daily cycles. Over a period of a week it is not unusual to see two daily cycles superposed, that is, a weekday cycle and a weekend cycle. There are also annual cycles that are associated with land use. In agricultural regions there may be periods of tilling, planting, cultivation and harvesting alternating with periods of low activity. Cyclic changes due to seasonal climatic changes play an important role in cycles of environmental noise, due to some extent to changes in foliation and changes in activity of human and animal populations. The following subsections provide guidance in setting up a measurement schedule that will adequately sample these cycles.

5.5.1.1 *Short-term Cycles*—Hour-to-hour sound levels should be estimated so the measurement schedule may be constructed to obtain data representative of the level changes that occur over the course of a day.

5.5.1.2 *Weekdays and Weekend Days*—In order that systematic differences between weekday and weekend sound levels can be evaluated, separate sequences should be established for weekday and weekend periods. (Tuesday through Thursday and Friday through Monday are frequently used, however the periods chosen should be specific to the community.)

5.5.1.3 *Seasonal Cycles*—The potential for systematic seasonal cycles should be evaluated and, if appropriate to the purposes of the measurements, the measurement schedule should provide for measurements at various times of the year to include the extremes of sound level. See 5.5.1.4.

5.5.1.4 *Documenting Temporal Changes in the Natural Ambient Level*—It is important that the investigator be aware of the potential for changes in ambient sound production (such as bird, insect and wind noise) because of changes in meteorological conditions. The plan shall require documentation of the occurrence of such a change. The plan shall also recommend that if the distinction between the two sound modes is important the time period in question be separated into two

distinct measurement sets. Otherwise the time period containing the interferences should be excluded from the measurements since the affected sound levels detract from the reproducibility of the data.

5.5.2 *Procedure For Setting Up a Measurement Schedule*—The following tools and procedures are recommended for expediting the preparation of a measurement schedule.

5.5.2.1 *Labeling Locations*—Assign unique numbers or letters to each measurement location. (If this was done during the location selection process do not renumber the locations.)

NOTE 9—A map showing the measurement locations and the local road network can be very helpful. The map prepared in the documentation of measurement locations is recommended (see 5.4.2).

5.5.2.2 *Establishing Sequence, by Location, of Measurement Sets*—The objective is to randomize the sequence of visits to the set of measurement locations while insuring that all locations are sampled equally during the measurement campaign. A true randomization, by location, of measurement sets could eliminate some locations from the measurement schedule or cause some locations to be oversampled. It is the intention of this procedure to not allow this. For this reason a separate, but not necessarily unique, non-repeating random sequence, by location, should be assigned to each cycle of measurement sets.

NOTE 10—It is left to the user to decide how the random sequences are selected.

5.5.2.3 As the random sequences for measurement sets are developed, prepare a table that lists the sequences in the order selected. Initially assign dates and times for each visit, taking into account the time required for each visit and travel time to the next location.

5.5.3 *Evaluation of Significance*—The following statement shall be made a part of the schedule section of the plan: "The significance of aggregate data from each location shall be evaluated on a daily basis. (See Annex A5 for evaluation of significance.) When it becomes obvious that additional visits to a location are not likely to produce an improvement in the data set, that location can be skipped when it appears in a sequence. Note that weekday and weekend sequences should be treated separately in this respect."

NOTE 11—When field analysis of the data shows that data significance has been achieved for a location over a period of seven to ten days, reduce the number of measurement sets scheduled for that site in favor of additional measurement sets for sites for which data significance has not been achieved.

NOTE 12—**Caution:** Care should be taken, however, to be certain that seasonal activities do not produce a short-term correlation effect that is not representative of long-term situation. An example is the daily periodic cycle of the level of highway noise. If measurements were unintentionally scheduled to coincide with peak traffic periods, one could not tell from the measurement results alone that the data were not representative of the entire day. To avoid such a possibility, the investigator should plan to visit measurement locations at times outside the schedule and make a personal assessment of current conditions, including random sound level meter readings.

5.5.4 *Reporting Method and Rationale For Measurement Schedule*—The schedule based on this guide shall be a part of the measurement plan and shall accompany the report for the measurement program. The location sequences, as well as the method used to obtain them, shall be included in the measurement plan. The measurement report shall include explanatory notations for measurement sets that have to be dropped or rescheduled.

5.6 *Equipment Requirements and Specification*—This section provides guidance in using the measurement scope (5.1) to determine minimum requirements for sound measurement equipment for performing the noise measurements and for physical measurements associated with the noise measurements. Any equipment that meets the minimum requirements may be used provided the features required to satisfy the requirements of the scope are considered in setting up the measurement plan. The following subsections deal with microphones, time weighting, band-pass filters, statistical data analysis, and microphone windscreens.

5.6.1 *Microphones*—Microphone characteristics of concern in optimizing a measurement system for a particular situation are the following: (*1*) frequency response, (*2*) directional response, and (*3*) self noise.

5.6.1.1 *Frequency Response*—The microphone selected for the measurements shall have a nominal frequency response range that includes the range of frequencies called for in the scope of measurements.

NOTE 13—Because microphones having greater frequency range generally have lower sensitivity, it may be necessary to consider a trade-off between self noise and frequency range. (See 5.6.1.3 and 5.6.4.3.)

5.6.1.2 *Directional Response*—The directional characteristics of microphones should be considered in their selection and use. This is especially important if there are nearby high-frequency sources of interest. High-frequency sound from distant sources (more than 90 m (300 ft)) will usually not be significant due to atmospheric attenuation. Microphones should be selected and oriented to provide the most accurate measurement of expected high-frequency sounds. See Appendix X3 for further information.

5.6.1.3 *Microphone Self Noise*—Microphone self-noise may constitute an interference in the measurement of sound levels. A copy of the self noise data for the microphone, generally supplied by the microphone manufacturer, should be consulted in determining if the microphone selected has an adequately low self noise. The plan should include the information or state that it is not available. See 5.6.4.3 for discussion of the system self noise.

5.6.2 *Characteristics of Sound Measurement Equipment*—The plan shall specify the characteristics of all equipment used to process the microphone signal, including but not limited to sound level meters, pre-amplifiers, filters, analyzers, and recording devices. This specification may be made either by limiting the equipment to specific makes and models that are known to provide the appropriate characteristics, or by specification of the characteristics without regard to specific instruments that may have these characteristics. (It is recommended that in the latter case, that the specified characteristics be associated with currently available equipment.)

5.6.2.1 *Band Pass Filters*—If measurements are to be made in octave bands or in fractional octave-bands, the plan shall specify filter sets that fulfill the objectives of the measurement, or of the measurement plan. Filters shall meet the requirements of ANSI S1.11.1985.

5.6.2.2 *Time Weighting*—The plan shall require the measurement system to include the appropriate capability to measure time-related characteristics (or to simulate equivalent meter response), required by applicable measurement procedures and by expected situations. Examples of such capabilities are slow, fast, impulse and peak sound level, and time-average sound level. See 3.2, Terminology C 634, and Guide E 1686 for details of these features.

5.6.2.3 *Statistical Data Analysis*—If statistical data, such as Percentile Levels (percent of time levels are exceeded), Time Average Sound Level (L_t), or Day-Night Average Sound Level (DNL), are required, the plan shall require that the measurement equipment include either appropriate analysis features, or the capability and equipment to store data for future analysis. In determining the requirements for storage, take into consideration the quantity of data to be stored for a data set, and the data handling rates necessary to acquire and store the appropriate amount of data.

5.6.3 *Microphone Protection*—This section describes precautions that are recommended for protection of microphones from various kinds of damage, and to reduce the likelihood of interference from wind interaction with a microphone.

5.6.3.1 *Microphone Windscreen*—The measurement plan shall require use of a microphone windscreen system, compatible with the microphone system and suitable for the conditions under which measurements are to be made. In selecting a windscreen, the recommendations of the microphone manufacturer, and the specifications of the windscreen shall be considered. See Appendix X4 for further details.

5.6.3.2 If available, the published wind-noise spectrum of the installed windscreen shall be compared with the spectrum of expected measured sound levels and an estimate of the influence of the windscreen on measured data shall be included in the measurement plan, as well as in the measurement report.

5.6.3.3 *Moisture/Humidity Protection*—Although it is universally considered to be inappropriate to perform outdoor sound measurements in the presence of precipitation or fog, circumstances can lead to exposure of a microphone system to rain, snow, fog, dew, or high humidity. Exposure to any of these forms of water can compromise the ability of a microphone to produce dependable results. For this reason it is not uncommon to use “weatherproof” microphone systems that isolate the water-sensitive parts of the microphone from atmospheric water sources. The measurement plan shall specify requirements for ensuring that the weatherproofing system does not compromise the acoustic performance of the microphone. Generally this can be accomplished by requiring adherence to recommendations of the microphone manufacturer and by requiring a statement of the manufacturer’s performance specification for the microphone weatherproofing system.

5.6.4 *Precision, Accuracy, and Calibration*—There are two areas in which precision and accuracy considerations apply: measuring of sound level and establishing locations (distance measurement). At a minimum, the plan shall require the following procedures related to precision, accuracy, and calibration.

5.6.4.1 *Field Adjustments of Sound Measurement Equipment*—It is highly desirable that during a series of related measurements, after initial calibration adjustment, no further adjustments shall be made to the instrument to make the calibration indication agree with the expected calibration value unless required by the measurement plan. Instead, the calibration record shall be used to standardize the data during subsequent data reduction and analysis. However, if there is some legitimate reason, and all parties agree, that the measurement plan shall require manipulation of the calibration control during the measurement program, a record shall be maintained of calibration adjustments over the course of the measurement. The record shall be retained with the field notes.

5.6.4.2 *Primary Calibration of Sound Measurement Equipment*—Within one year or another period specified by the measurement plan, prior to ending the measurement period, all equipment specifications claimed by the manufacturer shall be verified by an independent laboratory, using standards traceable to the National Institute of Standards and Technology, and following recommendations of the instrument manufacturer.

5.6.4.3 *System Self Noise*—When measuring very low sound levels the electrical self noise of the measuring equipment may compromise the data by masking the signal at one or more frequencies. If the data are being obtained in fractional octave bands such masking can be seen as a fixed minimum value in one or more bands. When measuring A-weighted levels, however, the effect of self noise will not be so obvious. During data analysis the self noise values are helpful in assessment of data validity. For this reason the measurement plan should include instructions regarding measurement and recording of the equipment self noise.

5.6.4.4 Any time it is anticipated that the level in any band of interest is less than 10 dB above the nominal self noise of the microphone and measurement system, the measurement plan shall require a check of the broad-band self noise at appropriate intervals.

NOTE 14—Appendix X5 provides a statement that may be included in 5.4.3 of the measurement plan, or modified to suit the situation.

5.6.4.5 When fractional-band measurements are being performed, the system self noise of each band should be checked at least once during the measurement period.

5.7 *Equipment for Physical Measurements*—The measurement plan shall include a section that specifies the equipment needed for physical measurements to support the acoustical data.

5.7.1 *Location Measurements*—To ensure an accuracy of 1 dB in sound level values obtained from calculations that involve distance or location measurements, the accuracy of the related distance and direction measurements shall be within 5 %.

5.7.1.1 *Distance*—Any instrument or technique that provides the degree of accuracy specified in 5.7.1 is satisfactory.

5.7.1.2 *Direction*—A pocket compass (desirable), used for site layout work and determination of wind direction.

5.7.1.3 *Elevation*—If the study area is undulating in nature, and the variation in elevation exceeds 2 m (6 ft), it is recommended that a topographical map be consulted for

estimating elevation of sound sources, potential receptors, and potential sound barriers.

5.7.2 *Meteorological Measurements*—It is important to observe and record wind speed, relative humidity, and temperature for potential effects on the instruments, and these factors plus wind direction for potential effects on sound propagation. For certain types of microphone calibrators barometric pressure shall be observed at the time of calibration. In some cases radio reports of meteorological conditions can be useful for meteorological data, however, it is preferable to use available general accuracy meteorological instruments to enable the measurement of:

5.7.2.1 *Wind Speed* (5 km/h or 2.5 mph increments),

5.7.2.2 *Wind Direction*, to the nearest of the eight common compass directions,

5.7.2.3 *Relative Humidity* (in 10 % increments),

5.7.2.4 *Dry Bulb Temperature* (in 2°C or 5°F increments),

5.7.2.5 *Barometric Pressure*, as specified by the (acoustic) calibrator manufacturer if required for the proper use of the calibrator. Note that the needed barometric pressure is the absolute pressure, not the pressure corrected to sea level as reported by the weather bureau.

5.7.3 *Photographs*—A camera, preferably with 35-mm film format and a wide-angle lens, should be carried by the measurement team for the purpose of documenting the equipment setup and surroundings at least once at each measurement location.

5.8 *Field Procedures*—Although the equipment set-up is done in the field, most of the decisions regarding location and placement of equipment, control settings, and other on-site procedures need to be made at the time the measurement plan is drawn up. When alternative actions are anticipated the rationale for selection of a particular option, based on circumstances, shall be included in the plan.

NOTE 15—See ANSI S12.9, Parts 2 and 3 for supplementary material.

5.8.1 *Microphone Placement*—The locations at which the measurements are to be carried out are prescribed according to guidelines from 5.4. Exact placement of the microphone at the location shall be governed by the following paragraphs.

5.8.1.1 Unless there is a requirement to place the microphone at a specific location, or if special circumstances prevail, the plan shall include the following instruction: "Support the microphone on a sturdy tripod or mast at a height between 1.2 m (4 ft) and 1.5 m (5 ft) above the ground. In suburban and rural settings, avoid placing the microphone tripod on a paved surface or in tall grass (in excess of 0.25 m (10 in.)). In urban situations (except in residential areas or parks) place the tripod on a surface that is representative of the area. The microphone location and height, as well as the surface condition in the area of the microphone, shall be described on the data sheet and in the report. If it is not possible, because of local conditions, to follow these requirements, this shall be stated on the data sheet and in the report."

NOTE 16—See Annex A1.

5.8.1.2 *Precautions*—The plan shall contain the following precautionary statement: "Care shall always be taken to position the microphone away from acoustically reflective surfaces that are not normally present at the location specified by the measurement plan. This includes any vehicle used in connection with the measurement program. In the absence of more specific guidance, the microphone should be placed at a point that is away from any such non-normal acoustically reflective surface by at least 2½ times the major dimension of that surface."

(1) In placing the microphone, use caution when electrical equipment is in the vicinity of a proposed measurement location, avoid requiring placement of measurement equipment, especially the microphone, directly under power lines, in the ground-plane array of radio or television transmitters, or close to transformers. In general, avoid establishing a measurement location close to power poles or lines. When such a location cannot be avoided, the plan should include a requirement to check the equipment for evidence of electrical interference and guidance in locating the microphone and other instruments to avoid the interference.

5.8.1.3 *Low-Frequency Tonal Source*—When low-frequency tones are present, and it is desired to obtain an accurate measurement of the low-frequency sound level, the height of the microphone above the ground surface can influence the result. If the source is nearby, the distance between the source and the microphone influences the measured value.

(1) The measurement plan shall require that such effects be tested for during set-up by moving the microphone slowly, both up and down, and along a line between the microphone and the sound source, taking care to observe the precautions in 5.8.1.2. The measurement plan shall include specific directions for addressing the situation if there is a consistent noticeable change in the level during the movement.

(2) In lieu of such direction, the plan shall require the report to include a comprehensive discussion of the procedure for locating the microphone. The provisions of Appendix X3, regarding microphone orientation, shall also be observed.

5.8.2 *Equipment Settings*—The plan shall include control settings (or ranges of settings) for all measurement, analysis, and recording equipment. It is recommended that the equipment settings be presented in tabular form to facilitate reference in the field. (A copy of the table, placed in a plastic folder, could be used conveniently by the field crew.) The plan shall provide the rationale for selection within each range.

5.8.2.1 *Weighting or Filter Bandwidth*—Specify weighting or filter bandwidth consistent with the purpose of the measurement. Consult applicable criteria for analysis bandwidth or weighting requirements. It is recommended that if more than one analysis channel is available, at least one should be used for A-weighted sound level.

5.8.2.2 *Averaging Time and Sampling Rate*—When using equipment with an analog meter, set the meter time weighting as called for in the governing document. Default settings should use slow response.

(1) When using digital measurement equipment, the default setting should be "FAST" unless the governing specification calls for slow. Set the sample rate to the value recommended by the equipment manufacturer.

5.8.2.3 *Measurement Duration, Dynamic Range, Maximum Level*—Set the measurement duration, dynamic range, and maximum range at values appropriate for the measurement situation. Consideration should be given to the possible occurrence of intrusive sounds such as vehicles, aircraft, trains, etc., as well as the relative levels of the equipment self noise and the lowest sound level anticipated during the measurement session. The dynamic range of the system may be smaller than the range of sound levels encountered. If this is the case it will be necessary to choose to forgo measurements at one extreme of the range. The choice, and the rationale for it should be included in the measurement plan, and shall be documented in the field log. The manner in which the instrument documents an out-of-range measurement should also be included with this information.

5.8.3 *Special Types of Sound*—The plan shall include guidance for situations in which the sound to be measured is characterized by impulses, tones, or infra-sound.

5.8.3.1 *Impulsive Sound*—In situations involving impulse sound events, the user should be aware that the "fast" and "slow" responses typically used to measure continuous sound do not measure the level of the impulsive sound accurately. To obtain accurate measurement of impulse peaks, other methods (for example, see ANSI S1.13) shall be used in conjunction with this guide. The presence of impulse shall be noted in the report. Any measurements in which data other than a narrative description of the impulse(s) are obtained shall require a measurement plan that prescribes the sampling rate, system response, and other pertinent guidelines. The plan should also include reference to standards that provide guidance, for example, ANSI S1.13, Section 8.4.1.

5.8.3.2 *Tonal Sounds*—When the presences of tones, defined in 3.2, is obvious, or anticipated, octave-band or fractional-band analysis should be included in the measurement. If, in the judgement of measurement personnel, the tonal portion of the sound is relatively constant, short-term band analysis is sufficient. However if the tone constantly or regularly changes in pitch or loudness, sufficient measurements shall be made to, in the judgment of the investigator, characterize the temporal as well as the spectral nature of the tones.

5.8.3.3 *Infrasound*—When there is reason to believe there is infra-sound present at an amplitude that may be significant in terms of the survey's objectives, care should be taken to assure that the microphones and measurement instrument have sufficient low-frequency response to adequately characterize the sound. Include octave-band or fractional-band measurements as appropriate.

NOTE 17—Infrasound may exhibit strong interference effects. Check for this by moving the microphone along a line that intersects the source, noting the change in level over a distance of a half wavelength (1 wavelength = (344/f) m, or (1127/f) ft, where f = frequency, Hz).

5.9 *On-Line and Post-Measurement Analysis of Data*—Processing of measurement data to present the results in terms of one or more metrics can be performed simultaneously with data acquisition when using measurement equipment that combines measurement and analytical capabilities. Alternatively, if sufficient data can be stored by the data acquisition equipment, the analysis can be performed later. The measurement plan should address this alternative in terms of which method is preferable. An example of a determining factor would be whether or not it is desirable to retain the raw data, for alternative processing for example. If post analysis is chosen, the analysis procedure shall be described in the measurement plan.

5.10 *Supporting Data*—The plan shall prescribe the format for documentation of the measurement. It is recommended that a separate data sheet be prepared for each measurement of a set of measurements. Documentation shall include the following information and data:

5.10.1 *Location Designation*—Each data sheet should include a space for entering an identifier that will positively associate each location with the description prepared during the location selection process. If a formal sampling plan is being followed, use the name or code assigned to the location by the sampling plan.

5.10.2 The date, start, and end time of the measurement. If the measurement is not within the time period called for by a predetermined plan, the reason for the deviation shall be stated.

5.10.3 *Concurrent Traffic Survey*—If analysis of the measurement results includes correlation of traffic data with sound level data, the plan shall prescribe the procedure for recording vehicle counts associated with each measurement set. The count(s) should also be specified if traffic is the dominant source of interest or a significant interference with another source of interest. The plan shall specify the format of the record and state the discriminants for vehicle type. Typical discriminants would include one or more of the following:

5.10.3.1 Passenger cars and light trucks,

5.10.3.2 Medium trucks and vans, and

5.10.3.3 Heavy trucks.

5.10.4 *Event Log*—Except in the case of non-attended measurements, the plan should also specify that a log be kept for noting the time of occurrence of non-traffic events that produce sound at a level sufficient to influence the ambient level at the time of occurrence. A rule of thumb for identifying such events is audibility to a person with normal hearing. For the most part these sources will be transportation related, however they could be intermittently operating equipment, air conditioning equipment, public address systems, or sporting events, to name a few, as well as animals and insects.

5.10.5 *Environmental Conditions*—Record environmental conditions that are representative of the time period for each measurement set. The information recorded shall include the following:

5.10.5.1 Temperature,

5.10.5.2 Relative humidity,

5.10.5.3 Barometric pressure (and altitude, if required for microphone calibration),

5.10.5.4 Wind speed (range if appropriate),

5.10.5.5 Wind direction (direction blowing from) in octants or multiples of 45 degrees,

5.10.5.6 Sky condition, that is, clear, scattered clouds, partly cloudy, mostly cloudy, overcast, and

5.10.5.7 Ground condition, that is, dry, dew, wet, snow.

5.10.5.8 Conditions shall be recorded at the beginning and end of the sound measurement set, and at least hourly if the set

is more than one hour in duration. Note the time and type of any unusual weather conditions or change. If significant for the purpose of the measurement, wind direction and speed should be measured and recorded more frequently, for example, at intervals of no more than 15 min.

NOTE 18—If the wind speed is close to the threshold at which measurements should be suspended, wind speed should be monitored continuously.

5.10.6 *Site Descriptions*—A brief written description of the measurement site shall be prepared, on site, at the time of the first measurement. Include a simple map or sketch showing the microphone location as well as distances and directions to structures, and ground types within 90 m (300 ft) of the microphone. The written description shall include a surface description, for example, bare earth, water, snow, vegetation (plant type, height, extent of foliation) of the ground surface under the sound path(s). It is recommended that photographs be taken during the measurement period to augment photographs taken during the selection of measurement locations. Both types of photos should be referenced in the report and included as documentation.

NOTE 19—See ANSI S12.9, Parts 2 and 3 for additional information on supporting data requirements.

6. Keywords

6.1 acoustical environment; attended/unattended measurement; calibration microphone; duration measurement; impulsive sound level data; low-frequency sound level data; measurement precautions; measurement schedule; measurement procedures; measurement location; meteorological interference; microphone placement; microphone protection; operator qualifications; outdoor sound level data; outdoor measurement; percentile level sound level data; post-measurement analysis; receptor location; sound level measurement; source location; statistical analysis; time-average level sound level data; tonal sound level data

ANNEXES

(Mandatory Information)

A1. IDENTIFYING AND MITIGATING INTERFERENCES

A1.1 Measurements intended to provide detailed spectral and temporal sound level data are subject to interferences from a number of sources. The most significant of these are discussed in A1.2. Additional information is available in ANSI S12.9, Parts 2 and 3.

A1.1.1 An effective way to avoid the influence of interferences is to include a requirement to have an operator/observer present at all times during such measurements. The observer, in addition to monitoring potential interferences such as wind, precipitation, and site visitors, can interrupt or terminate the measurements when the potential effect of pending or existing interference is judged to be significant, or when guideline limits established by the measurement plan are exceeded.

A1.1.2 This annex describes several common sources of measurement interference. It also presents recommendations for avoiding the effects of these interferences.

A1.2 *Interferences*—The following subsections list representative interferences and discuss mitigating measures:

A1.2.1 *Nearby Noise Sources*—Establishing a measurement location too close to a noise source will result in masking of noise from more distant sources. In some cases it may be necessary to make such measurements to document the nearby noise source, however additional measurements should be made (*1*) with the local noise source silent in order to assess its effect on the local receptors, and (*2*) at increased distances to identify the region of influence of the source. Measurements obtained with a nearby noise source active should be so identified so they will be properly used in the characterization a large area. Data requirements include location of the source relative to other sources and to the measurement location. (The reader is referred to ANSI S12.9, Parts 2 and 3, for further guidance on performing measurements in the presence of data-contaminating sound, and on analysis of data obtained under such circumstances.)

A1.2.2 *Electromagnetic Radiation*—Radiation from high voltage transmission lines, or strong television or radio signals may affect the measurement system, causing an erroneous indication. The operator should use caution when this type of equipment is nearby, being especially careful to avoid being directly under power lines, in the ground plane array of radio or television transmitters, or close to transformers. Anomalies caused by such interference can usually be detected by using the earphones with the analyzer's ac output. Comparison with results obtained with a dummy microphone could be helpful in quantifying the effects of EMR, but the resulting measurements would not necessarily show the effects of the EMR on other components of the measurement system.

A1.2.3 *Vegetation*—Locations near trees may experience interference from wind-induced sounds. Such locations are generally satisfactory if a single location is being characterized because at short distances the wind-induced sound is part of the acoustic environment. Such locations should generally not be used in characterizing large areas that do not have uniformly dense tree growths.

A1.2.4 *Barriers*—Natural or man-made barriers should be carefully considered if they exist. As in the case of vegetation/wind combinations that produce sound, the influence of a barrier may be essential to the acoustic environment of a single site, but it may eliminate the location from consideration for large area characterization.

A1.2.5 *Measurement-Related Interference*—The operator/observer, as well as all visitors and on-site support staff should be made aware of the importance of not engaging in activities that create local sounds. Examples of activities to be avoided while measurements are in progress are listening to radios or other entertainment devices, talking, walking on gravel, leaves, or twigs, use of radio-telephones (electromagnetic interference), or operating vehicle engines.

A1.2.6 *Wind-Generated Noise*—Appropriate guidelines for measurements in wind should be established in the measurement plan.

A1.2.7 *Wind-Microphone Interaction*—Interaction of wind with the microphone system generates sound that is not a part of the environment, but which interferes with the ability of the measurement system to accurately measure sound at the low end of the measurement range. The measurement plan shall require that care be taken to reduce interference from this source, and to estimate and document the extent to which the data are contaminated by noise from this source. Refer to Appendix B for details on reducing interference from this source.

A1.2.8 *Wind Interaction With Vegetation and Structures*—Sounds produced by wind blowing through vegetation, such as trees or shrubs, or interacting with structures, increase the sound level in the vicinity of the vegetation or structure, but the influence does not extend over a great distance. In the case of grass, or agricultural crops however, a uniform shift in ambient sound level may occur over an extensive area. The implications for planning a sound measurement are that the measurement location can be near a local sound source, that is, vegetation or structure, if data are needed for a specific location. Otherwise, the location should be chosen to be sufficiently far away from such sources, other than extensive tracts of grass, that they do not measurably influence the area ambient level.

A1.2.8.1 *Additional Measurements to Assess Wind Influence*—Depending on the use to be made of the measurement results, it may be appropriate to obtain data for windy and calm periods separately to evaluate the range of sound levels associated with a range of wind conditions. It is recommended that this issue be addressed in the measurement plan.

A1.2.9 *Atmospheric Effects*—A recognized way to identify the potential for atmospheric influence at a particular location is to sample the same location at the same time in different days, weeks, or seasons. Sampling at different times of the day will be useful if it can be shown independently that source levels remain constant for all samples. The measurement plan should address these factors if they are critical to the application of the measurement results.

A2. CONSIDERATIONS FOR DECISION ON REQUIRING ATTENDED MEASUREMENTS

A2.1 Paragraph 5.2 requires agreement between the performing organization, the client, and representatives of cognizant regulatory bodies, regarding the necessity of having a qualified person in attendance during all sound level measurements in which sound level data are automatically recorded at regular intervals.

A2.2 *Factors to Consider:*

A2.2.1 *Interferences*—There is always the possibility, in the case of unattended measurements, of undetected interferences of the type described in 3.2.5 and Section 5. The extent to which the interferences influence the measurement results depends on the sensitivity of the data to interference. One should consider the consequences of errors in the data that are a result of interference. The cost to the client of post-measurement processing the data, or to remediate noise impacts after the fact should be weighed against the cost of monitoring the measurements.

NOTE A2.1—*Exception:* In situations involving only the determination of the sound level exceeded 90 % of the time (L_{90}), monitoring is less critical because the analysis process strips away most of the interference related to spurious sound sources.

A2.2.2 *Editing Data*—The overall effect on data accuracy can also depend on the ability of the investigator to detect and remove corrupted records from the data files during post-measurement analysis and to isolate into separate measurement sets the results of measurements made under significantly different conditions. This in turn depends on the manner in which the measurement data are recorded. If data are recorded in blocks representing relatively short segments of the total measurement period, and if it is possible to remove corrupted blocks and adjust analytical results appropriately, the need for continuous attendance by an observer is less critical than it would be otherwise.

NOTE A2.2—If editing the data files to remove flawed data is acceptable, additional confidence in the edited results may be obtained by making an analog tape recording of sound, or a time history recording of sound level during the measurement. These records may then be consulted during the editing process.

NOTE A2.3—In the case of a data recording procedure that employs decimation processes, for example, recording only the average, peak, or other statistical values representative of blocks of data, the time resolution of the data is reduced and detecting flawed data becomes more difficult. It is recommended that such measurements always be monitored.

A2.3 If it is decided to use the "unattended" option, the following are mandatory for measurements made in connection with environmental impact assessment:

A2.3.1 *Documentation of Justification for Using the "Unattended" Option*—The plan shall state that the matter was considered. The rationale for the decision shall be stated briefly.

A2.3.2 *Documentation of Dealing with Interferences*—A procedure, based on Annex A3, shall be used to detect, report, and mitigate anticipated interferences. An outline of the procedure shall be included in the measurement plan. An estimate of the possible effect on overall accuracy of the results, of not using the "attended" option, shall be included in the measurement plan.

NOTE A2.4—If desired, Annex A3 may be incorporated in the plan by reference with the understanding that any deviations from Annex A3 will

be stated in the measurement report.

A2.3.3 *Documentation of Data Editing Procedures*—The measurement plan shall specify the manner in which the measurement report will document the nature and extent of data editing during analysis.

A3. QUALIFICATION AND TRAINING OF OPERATOR

A3.1 *Operator Qualifications*—To qualify as an operator for attended or unattended measurements covered by a specific measurement plan, an individual shall have received training in setting up and operating the noise measurement equipment designated in the measurement plan. The training shall have been provided by one of the following:

A3.1.1 The manufacturer of the equipment or a representative designated by the manufacturer as a qualified operator and trainer,

A3.1.2 An individual who has been certified by the manufacturer to have been trained according to A3.1.1, and

A3.1.3 A person who is a sound measurement professional and who has performed measurements using the same equipment, or equipment comparable to that specified in the measurement plan.

A3.2 *Training*—Operator training shall include demonstration of the proposed operator's understanding of the measurement plan and familiarity with the objectives of the measurement and the rationale for the measurement procedures. The training shall also familiarize the trainee with potential interferences and their effects on measurement results.

A4. DEFINING THE STUDY AREA AND SELECTING MEASUREMENT LOCATIONS

A4.1 *Introduction*—The material provided in this annex and in Appendix X1 illustrates the process for selecting measurement locations. Use of a documented procedure for selection of measurement locations in lieu of the procedure given in Appendix X1 is optional. If the method shown is used it can be included by reference to this guide, noting any deviations from the procedure as given.

A4.2 *Identify and Document the Study Area*—If the study area has not been defined by the client or sponsoring agency, proceed to identify the noise sources and receptors that should be included in the study area.

NOTE A4.1—In the case of an area that encompasses only a few acres (or hectares), it is possible to obtain the necessary information by touring the area by automobile or on foot, and by making handwritten notes. However, for larger areas this approach may not be appropriate because of the volume of information to be obtained and analyzed (see X1.1).

A4.2.1 In the case of a study designed to evaluate the potential for impact of a planned noise source to be added, or to monitor the effect of a noise source after it has been added, the study area will be the area within the acoustical influence of the new source. Include any existing noise sources, for example, major highways, machinery, etc., in the study area if they contribute sound to the area of acoustic influence of the subject source(s).

A4.2.2 If the purpose of the study is to document the acoustic character of a single location, the study area is the location and its immediate surroundings. Only one measurement location is required in such cases.

A4.2.3 The special case of monitoring of plant boundary line A-weighted sound levels, using hand-held instrumentation is covered in Guide E 1014.

NOTE A4.2—In Guide this is found in the Procedure section under Survey Around a Site Boundary.

NOTE A4.3—The size of the study area may require adjustment if initial sound measurements show unexpected sound levels, and correspondingly greater or less area of influence, than anticipated.

A4.3 *Identify and Document Sources and Potential Receptors of Noise*—Using the guidelines given below and in 5.4.1 and 5.4.3, pick out all identifiable noise sources and potential noise receptors in the identified study area. Appendix X1 provides a methodical approach to identifying potential measurement locations. If this approach is used, Appendix X1 may be referenced in Section 4 of the plan. If a different approach is used in preparing the plan, the rationale for the approach shall be included in Section 4 of the plan and details either included as an appendix, or the source referenced.

A4.4 Prepare a worksheet for each noise source or receptor location considered, including those that may eventually be rejected. Each worksheet should include the following information:

A4.4.1 For noise receptors, a narrative description of the location, including information on the number and relative location of surrounding structures and topographic features that could influence sound propagation in the immediate area. Also, list the direction and approximate distance to planned and existing noise sources.

A4.4.2 For noise sources, in addition to a narrative description of the location, include information on the direction and distance to structures and topographic features that could influence sound propagation in the immediate area.

A4.4.3 The rationale, with references to appropriate sections of this section, for selecting this location for measurements.

A4.4.4 Photographs of the measurement location and a panoramic set of photographs taken from the measurement

location. If possible, include a small sign designating "North" in the appropriate photo of the panoramic series.

A4.5 *Number of Measurement Locations Required*—While there is no specific number of measurement locations for any measurement plan, the following guidelines shall be used.

A4.5.1 When selecting locations for performing measurements to characterize the sound level at a specific point, a single measurement location shall be sufficient.

A4.5.2 If it is necessary to show the degree of spatial uniformity of sound level over an area containing more than one sound receptor; or if several sound sources are separated sufficiently to affect multiple receptors differently, the number of measurement locations selected shall be sufficient to show variations caused by the following factors:

A4.5.2.1 Localized sound sources within, or near, the area to be characterized,

A4.5.2.2 Focusing (or deflection) of sound from remote sources by meteorological effects,

A4.5.2.3 Shielding by topographic features, and

A4.5.2.4 Source directionality.

A4.5.3 *Select Representative Measurement Points*—Having identified the points for which sound level measurements are needed, examine the points for possible redundancy, for example, multiple points expected to have similar sound level characteristics. It may also be desirable to omit points at which no change in sound level is anticipated.

NOTE A4.4—It may be necessary to include some of these points in the measurement plan until initial measurements show them to be redundant or outside the area of influence of the noise sources being considered.

NOTE A4.5—If the results of the measurements will be used in modeling a proposed sound source, measurement locations should include points that are representative of all potential receptors within the area of influence of the new source.

NOTE A4.6—Appendix X2 is a list of resources that are helpful in selecting measurement locations.

A5. ANALYSIS OF DATA SIGNIFICANCE

A5.1 For the time being, data significance is achieved when one can predict the outcome of the next set of measurements through examination of data acquired to date. A separate guide to evaluating data significance with a prescribed degree of precision is planned and will include this annex.

APPENDIXES

(Nonmandatory Information)

X1. PROCEDURE FOR SELECTING MEASUREMENT LOCATIONS

X1.1 *Introduction*—The material provided in this appendix illustrates the process for selecting measurement locations. Use of a documented procedure for selection of measurement locations in lieu of the procedure given in this appendix is optional. If the method shown is used it can be included by reference to this guide, noting any deviations from the procedure as given.

X1.2 *Map Analysis*—When it is necessary to acoustically characterize a large area having diverse populations of sound receptors and sources, a useful technique involves a preliminary map analysis of sound sources and receivers. During a familiarization tour of the estimated study area, noise sources, including proposed sources, are identified on a detailed scale drawing, such as a 7½ min topographic map. Areas of representative ambient sound levels are estimated on the basis of population density and noted on the map. Measurement locations are then selected on the basis of the expected influence on the ambient levels by the identified sound sources.

NOTE X1.1—If the measurement plan is to include acquisition of data for use in a propagation model for determination of the effect of introducing a new sound source, use of this technique will require estimating the sound level produced by the planned new source at incremental distances from the source.

X1.3 Using the map as a guide, divide the study area into areas of similar population density. Refer to Table X1.1 and select the appropriate DNL criterion value from the row corresponding to the estimated population density. Write the corresponding DNL criterion value (Table X1.1) in each of the population areas.

X1.3.1 Identify possible measurement locations by selecting one of the following scenarios and using the corresponding analysis:

X1.3.1.1 No predominant stationary sound sources presently in, or influencing the study area. This is the least complex

TABLE X1.1 Typical Values of Yearly Day-Night Average Sound Level for Various Residential Neighborhoods Where There is No Well Defined Source of Noise Other Than Usual Transportation Noise[A]

Neighborhood Type	Population Density		Day-Night Level (DNL)
	People/km^2	People/mile^2	
Rural (undeveloped)	8	20	35
Rural partially developed	23	60	40
Quiet suburban	77	200	45
Normal suburban	240	600	50
Urban	770	2000	55
Noisy urban	2300	6000	60
Very noisy urban	7700	20 000	65

[A] Adapted from *Guidelines for Preparing Environmental Impact Statements on Noise*, National Research Council, National Academy of Sciences, Washington, DC, 1971, page IV-7.

situation. Choose enough measurement locations to document existing sound levels at representative receptors within the study area. Select one or more of these locations to include the range of ambient sound level as influenced by community activities and transportation-related noise sources. Choose one representative location in each incremental population area. Use the method described in X1.3.1.

X1.3.1.2 One predominant stationary sound source in, or influencing, the study area (not including a source to be added). This scenario is of interest because some receptors may be directly influenced by sound from the existing sound sources. In addition, a large part of the study area may be influenced by these sources. Use the method described in X1.3.2.

X1.3.1.3 Several significant sound sources at various places in or near the study area. Use the method described in Section X1.3.2.

X1.3.1.4 In the case of no specific sound sources, or no planned new noise source, select a measurement location in at least one of each of the incremental population areas.

X1.3.2 In the case of specific noise sources near or within one or more of the population density zones, select a measurement location at a distance of 50 ft from each representative line or point source (for area sources the distance should be at least twice the longest dimension of the source, but not less than 50 ft) and, if possible, at least 50 ft from a residence or roadway. Draw a circle with a radius equal to 50 ft, centered on the noise source. Using data from Tables X1.2 and X1.3, estimate the radii of concentric circles for consecutive 5 dB attenuations of sound from the source. Draw and label each concentric circle with the expected A-weighted DNL due to each source. For example, the estimated DNL at 50 ft minus the net reduction for each of the circles. Continue these circles out to a point at which DNL is 5 dB less than the lowest criterion value or expected ambient through which the current circle passes.

NOTE X1.2—If circles of like levels overlap, take into account the fact that the sound levels will combine to produce a higher level.

X1.3.3 In the case of a planned noise source, continue the construction started in 5.5 and draw concentric circles around the planned source at distances representing 5 dB decreases in expected source DNL. Continue these circles out to a point at which DNL is 5 dB less than the lowest criterion value, or ambient level, through which the current circle passes.

TABLE X1.3 Reduction of Octave-Band Sound Level[A] with Distance from a Point Source at a 50-ft Reference Distance

Distance		Octave-Band Center Frequency, Hz								
m	ft	31	63	125	250	500	1 k	2 k	4 k	8 k
15	50	0	0	0	0	0	0	0	0	0
27	90	5	5	5	5	5	5	5	5	6
49	160	10	10	10	10	10	10	11	11	12
85	280	15	15	15	15	15	16	16	18	19
137	450	18	18	18	18	20	20	21	23	24
198	650	22	22	22	23	23	24	25	28	32
335	1100	27	27	28	28	29	30	33	39	46
488	1600	30	31	31	32	33	35	38	47	58
670	2200	34	34	35	35	37	40	44	58	59
975	3200	37	37	38	39	42	45	52	71	93
1220	4000	38	38	39	41	43	48	55	76	101
1524	5000	42	42	44	45	49	55	65	95	130
1920	6300	44	45	46	48	53	61	74	111	150
2713	8900	48	49	51	54	61	72	90	143	150 +

[A] The values in this table include attenuation caused by spherical spreading of the sound energy plus an approximation to attenuation caused by interaction with the air. A number of tables giving the appropriate adjustments for various combinations of temperature and relative humidity are published. One such table may be found in Handbook of Noise Control, 2nd Ed., C. M. Harris, McGraw-Hill, 1979. There is also an ANSI standard that may be used in calculating the values of molecular attenuation.

X1.3.4 Table X1.2 is an example worksheet. To create the table illustrated in Table X1.2, do the following:

X1.3.4.1 In Column 2, enter octave-band sound levels, estimated or measured, for a point 50 feet from the sound source.

X1.3.4.2 Using Table X1.3, enter octave-band attenuation values in Columns 3, 5, and 7 for distances of interest.

X1.3.4.3 In Columns 4, 6, and 8, enter the results of subtracting the values in Columns 3, 5, and 7 from values in Column 2.

X1.3.4.4 Apply appropriate “A” weighting factors to each of the unweighted octave-band values in Columns 4, 6, and 8. (This step is not shown in the table. The results are shown in the bottom row, labeled “A-Wtd.”)

X1.3.4.5 Combine the resulting A-weighted octave band values to obtain A-weighted sound level for each distance.

X1.4 Select representative residences or other sensitive noise receptors as close as possible to points that satisfy the following conditions:

X1.4.1 Located near the center of each L_{dn} area,

TABLE X1.2 Example Worksheet for Tabulating Sound Level at a Distance[A,B]

(1) Octave Band Freq. Hz	(2) Level At 15 m (50 ft) dB re 20 µPa	(3) 27 m Band Attenuation dB	(4) 90 ft Band Level dB re 20 µPa	(5) 49 m Band Attenuation dB	(6) 160 ft Band Level dB re 20 µPa	(7) 85 m Band Attenuation, dB	(8) 280 ft Band Level dB re 20 µPa
31	92	5	87	10	82	15	77
63	95	5	90	10	85	15	80
125	96	5	91	10	86	15	81
250	96	5	91	10	86	15	81
500	95	5	90	10	85	15	80
1 kHz	90	5	85	10	80	16	74
2 kHz	87	5	82	11	76	16	71
4 kHz	80	5	75	11	69	18	62
8 kHz	65	6	59	12	53	19	46
A-Wtd	96 dBA	...	91 dBA	...	86 dBA	...	81 dBA

[A] This method is to be used only in developing a sampling plan. It uses approximations, rules of thumb, etc., and is not to be used for determining actual day-night sound levels.

[B] See X1.3.4 for instructions for use of this table.

X1.4.2 Located close to one of the concentric circles,

X1.4.3 Located on a line of sight to the projected source,

X1.4.4 Located at least 100 feet from any existing major sound sources (500 ft for extended sources).

NOTE X1.3—If any combination of DNL area and concentric circle does not have a noise receptor, examine the study area for a receptor that is in the same combination of levels. Only one such location need be considered for measurements. If there is no such location, select one that is remote from previously designated locations, but that otherwise satisfies the conditions in X1.4.

X1.5 *Eliminate Duplicate Locations*—Evaluate the selected locations for redundancy, eliminating those that clearly would provide duplicate data under conditions identical to those at other locations (unless duplicate measurements are desired to improve confidence).

X1.6 *Field Verification*—At the earliest possible date, before starting the formal sound measurements, visit each location for the purpose of verifying validity of the selection. At this time photographs or a videotape should be made for use in briefing the measurement team and for documentation purposes. It is recommended that preliminary sound measurements be made to get an idea of sound levels of background and any sound sources present.

X2. SUGGESTED RESOURCES FOR USE IN SCREENING AN AREA FOR POTENTIAL MEASUREMENT LOCATIONS

X2.1 Experience has shown that use of one or more of the resources listed in X2.1-X2.6 can be very helpful, especially if a large area is included in the study area.

X2.2 *Maps*—One or more 7½ min topographic sheets[4] can be useful as a base drawing when the study area exceeds 1 km in any dimension. They are well suited to showing the spatial relationships of noise sources and potential receptors. In addition, these maps, which are a convenient size, show the topography at a scale that is useful in evaluating the potential for topographic sound barriers.

NOTE X2.1—For locations in the U.S., the United States Geological Survey 7½ min topographic series of maps are suggested.[4] The scale for these sheets is 1:24 000 in which 1 cm on the map represents 240 m (1 in. represents 2000 ft). (See 5.4.1.1.)

X2.3 *Aerial Photographs*—A level of detail greater than that available from the USGS 7½ min topographic series is available at the same scale in aerial photographs. Available for most populated areas from realty service organizations, (local regional planning organizations often have reproducible copies from which prints can be made) these photo-maps show the exact locations of structures, wooded areas, and other features that are helpful in identifying noise propagation paths and noise sources.

[4] Available from United States Geological Survey, Washington, DC, or from most local map stores.

X2.4 *Site Photos*—Color photographs are useful in recalling details when reviewing candidate measurement locations. These photos can be made with a camera with wide-angle lens (inexpensive disposable cameras with wide angle lenses are available). The photographs also provide documentation for sites that are selected. If resources are available, use of a video camera provides more detail than still photos. In addition the video and audio simplify reviewing field trip data.

X2.5 *Bearing*—When visiting a candidate location, a magnetic pocket compass provides instant orientation, often not otherwise possible, especially on overcast days. (The user is cautioned to make sure the compass reading is not strongly influenced by a local magnetic source.)

X2.6 *Distance*—Many distances can be scaled from a 7½ min map, however distances less than 200 ft cannot be scaled to the 5 % accuracy required for acoustic modeling. For this reason, distances less than 200 ft should be measured using a 50- or 100-ft tape measure. If restricted access precludes using a surveyor's tape, use of an optical range finder is recommended.

X2.7 *Location*—If the planning involves many locations over a wide area, the use of a Global Position Satellite (GPS) receiver should be considered. Inexpensive portable models provide location coordinates within an accuracy of several feet.

X3. MICROPHONE DIRECTIONALITY

X3.1 The plan should include provision for including the effect of microphone directionality in selection of a measurement microphone. At a minimum the plan should require following the microphone manufacturer's recommendation for orientation. If the manufacturer's guidance for orientation is not provided, the plan shall require an orientation from X3.2 or X3.3.

X3.2 If the measurements are being made with a microphone having random-incidence response, the preferred mounting for this application is to have the microphone diaphragm in the horizontal plane. For most microphones this corresponds to mounting with the axis of cylindrical symmetry of the microphone in a vertical line (the microphone pointing up). An exception to this rule applies when sound from a

specific source is being measured. In this case the microphone should be pointed so there is a 70° angle between the axis of cylindrical symmetry and a line connecting the source location and the microphone location.

NOTE X3.1—**Caution:** A microphone mounted this way is especially sensitive to sound from low-flying aircraft. Unless such data are included in the measurement objective, provision should be made for pausing the measurement during these events. If such data are to be included, adjustment for the normal-incidence sensitivity of the microphone should be applied to the maximum values obtained.

X3.3 If the measurements are being made with a free-field microphone, it may be desirable to orient this type microphone as specified by the microphone manufacturer for this type of measurement. Generally the specification requires the line connecting the source and the microphone to be aligned with the axis of cylindrical symmetry of the microphone body, (point the microphone toward the sound source).

X4. DEALING WITH WIND-MICROPHONE INTERACTION AS AN ACOUSTIC INTERFERENCE

X4.1 The information in this appendix is provided as a guide to identifying and correcting errors due to interaction of wind with the measurement microphone.

X4.2 *Wind-Microphone Interaction*—Air movement past a microphone produces aerodynamic effects that are interpreted by the instrumentation as sound. These effects, which appear as loud pops and rushing sounds in a monitoring earphone, produce measurement results that are not accu-rate. The inaccuracy can be manifested as sound levels being indicated higher than they are, or in temporary cessation of measurement, accompanied by false indications caused by circuit overloads. Unless appropriate steps can be taken to eliminate the effect of the wind on the microphone, measurements should not be carried out when the wind speed exceeds the value at which interference occurs.

X4.3 *Determining Maximum Acceptable Wind Speed*—In planning a set of measurements, the minimum sound level, in terms of frequency range and the narrowest frequency band of interest, should be established and stated in the scope of the measurement. This information should then be used, together with microphone and windscreen specifications, to arrive at a maximum acceptable wind speed for measurements. Some thought should be given to the change in ambient sound level that accompanies an increase in wind speed. In many cases the minimum sound level of interest will also increase with wind speed, offsetting some of the undesirable effects of wind on the measurement microphone.

X4.4 *Selection of Microphone and Windscreen Combination*—Some microphone manufacturers publish tables or charts showing the spectrum of wind-generated noise for bare microphones. The information available in these charts provides a reasonable approximation of the wind response characteristics of comparable microphones for which no published charts are available. Wind-screen manufacturers provide wind-noise attenuation data, and measurement attenuation, for various windscreen sizes and materials. Examination of the manufacturers' data will show that the greatest wind-induced noise occurs at low frequencies, decreasing in magnitude as the frequency of interest increases. A combination of windscreen and microphone should be selected to permit measurement at the minimum sound level determined in X4.3.

NOTE X4.1—Consideration should be given to the sound-attenuation characteristics of the windscreen chosen, and to the maximum level that the chosen microphone can measure without distortion.

X4.4.1 If appropriate for the purposes of the measurement plan, and the measurement equipment permits, specify use of an anemometer with the capability to actuate a "pause" switch on the measurement system when wind speed exceeds a selected value.

X5. OPTIONAL SELF NOISE STATEMENT

X5.1 The following statement can be incorporated in the measurement plan:

X5.1.1 During the time period that measurements are being made, the electrical self noise of the measurement system, including the microphone or microphone preamplifier system, or both, shall be measured at least daily, (before starting measurements). This may be accomplished using one of several available techniques.

X5.1.1.1 By covering the microphone with a suitable acoustic isolator, (To be effective the isolation device used should provide isolation at all frequencies of interest. The sound transmission loss in each fractional band of interest should be sufficient to reduce the highest ambient band level (at the time of the measurement) to 10 dB less than the lowest ambient level of interest.) or

X5.1.1.2 By temporarily replacing the microphone cartridge with a dummy microphone recommended and approved by the microphone manufacturer, and recording the indicated sound level(s).

NOTE X5.1—Some equipment provides for turning off the microphone bias voltage, in effect making the measurement microphone a dummy microphone. (Note that this does not check the microphone.)

X5.1.2 If the data will be post-measurement processed by computer, it may be desirable to record the self noise data daily, otherwise the self noise value(s) should be entered in the daily log. (See 5.10.)

X6. RECOMMENDATIONS FOR INCORPORATING REGULATORY INFORMATION

X6.1 *Regulatory Information*—If the measurement is required by, or results of the measurements will be reviewed by, a regulatory agency, it is highly recommended that the following information be incorporated or referenced.

X6.1.1 *Regulatory Bodies*—If the measurement is required by, or results of the measurements will be reviewed by, a regulatory agency, give the names and addresses of cognizant regulatory bodies with respect to noise control requirements. If the measurements are being performed for the private use of a non-government client, this requirement does not apply.

X6.1.2 *Applicable Regulations, Ordinances, or Codes*—Include a list of relevant regulations, ordinances, or codes relative to outdoor sound levels.

X6.1.3 *Measurement Requirements*—Include a summary of measurement requirements, including data format, as given in the relevant laws or codes.

X6.1.4 *Regulatory Criteria*—Summarize applicable regulatory criteria, as given in the relevant regulations, ordinances, or codes. An example of a regulatory code is a property-line noise limit.

X6.1.5 *Non-Regulatory Criteria*—Cite or summarize non-regulatory criteria, and if applicable, measurement requirements, specified in contractual or other legally binding documents. (Examples are criteria for sleep interference, speech interference, community annoyance, or building vibration.)