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Standard Test Method for Conducting Outdoor Sound Measurements Using a Digital Statistical Sound Analysis System[1]

This standard is issued under the fixed designation E1503; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

This is one of a series of standards on the measurement and evaluation of community noise. Others in the series include Guide E1014 which covers manual measurement, using a simple meter, and analysis of the resulting data, and Guide E1780, which covers measurement of sound received from a nearby fixed source.

1. Scope

1.1 This test method covers the measurement of outdoor sound levels at specific locations using a digital statistical sound analysis system and a formal measurement plan.

1.1.1 This test method provides basic requirements for obtaining either a single set of data or multiple sets of related data. However, because there are numerous circumstances and varied objectives requiring multiple sets of data, the test method does not address planning of the measurement program.

1.2 The use of results of measurements performed using this test method include, but are not limited to, the following:

1.2.1 To characterize the acoustical environment of a site,

1.2.2 To characterize the sound emissions of a specific sound source which exhibits a temporal variation in sound output, and

1.2.3 To monitor the effectiveness of a noise impact mitigation plan.

1.3 This test method is intended to be used in conjunction with a measurement plan that references this test method. Changes or additions to the provisions of this test method shall be clearly stated in the plan.

1.3.1 In the event it is necessary, for example, because of time constraints, to conduct measurements without first formalizing a plan, this test method can be used if an operator/observer whose qualifications are satisfactory to both the performing organization and the client is present at all times during the measurements and who complies, to the extent possible, with all the applicable requirements of this test method, including record keeping.

1.4 The data obtained using this test method enable comparison of sound level data with appropriate criteria.

1.4.1 The data obtained with this test method can be used in the 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 which will be used for this purpose.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *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:*[2]

C634 Terminology Relating to Building and Environmental Acoustics

E1014 Guide for Measurement of Outdoor A-Weighted Sound Levels

E1686 Guide for Applying Environmental Noise Measurement Methods and Criteria

E1780 Guide for Measuring Outdoor Sound Received from a Nearby Fixed Source

[1] This test method is under the jurisdiction of ASTM Committee E33 on Building and Environmental Acoustics and is the direct responsibility of Subcommittee E33.09 on Community Noise.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

2.2 *ANSI Standards:*[3]
S1.11 Specifications for Octave-band and Fractional Octave-band Analog and Digital Filters [3]
S1.13 Measurement of Sound Pressure Levels in Air
S1.17 Microphone Windscreens - Part 1: Measurements and Specification of Insertion Loss in Still or Slightly Moving Air
S1.40 Specification for Verification Procedures for Sound Calibrators[3]
S1.43 Specifications of Integrating-Averaging Sound Level Meters
S12.9 Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 2: Measurement of Long-Term, Wide-Area Sound and Part 3: Short-term Measurements with an Observer Present
2.3 *IEC Standards*
61672–1 Electroacoustics - Sound Level Meters - Part 1: Specifications

3. Terminology

3.1 For definitions of terms, including the following used in this test method, see Terminology C634: dummy microphone, interference, impulsive sound, measurement plan, measurement set, percentile level, self noise and time-average sound level.

3.2 *Definitions of Terms Specific to This Standard:*
3.2.1 *digital statistical sound analysis system*—combination of a sound level meter, either analog or digital, interfaced with a digital data storage device, and a digital statistical analyzer, for sampling environmental sound levels over a specified timed interval.
3.2.1.1 *Discussion*—For the purposes of this test method, a generic analyzer having the necessary features for the intended measurement and meeting the requirements of ANSI S1.11, and ANSI S1.43 is assumed.

4. Significance and Use

4.1 This test method deals with methods and techniques which are well defined and which are understood by a trained acoustical professional. This test method has been prepared to provide a standard methodology which, when followed, will produce results which are consistent with requirements of government and industry, and which can be validated using information gathered and documented in the course of the measurement program.

4.2 There are numerous situations for which outdoor sound level data are required. These include, but are not limited to the following:
4.2.1 Documentation of sound levels before the introduction of a new sound source as a reference for assessment of the noise impact caused by a proposed facility and associated activities,
4.2.2 Comparison of sound levels with and without a specific source (for example, assessment of the impact of an existing source), and
4.2.3 Comparison of sound levels with criteria or regulatory limits (for example, indication of exceedance of criteria or non-compliance with laws).

4.3 This test method provides a means for operating a sound analysis system which incorporates digital circuits for processing and storing sound level data, documenting conditions under which the measurements were performed, and reporting the results.

4.4 This test method provides the user with information to (*1*) perform and document statistical analysis of outdoor sound level over specific time periods at specified places, and (*2*) make and document the physical observations necessary to qualify the measurements.

4.5 This test method can be used by individuals, regulatory agencies, or others as a measurement method to collect acoustical data for many common situations. The data are collected in a format determined by the capabilities of the equipment, equipment operational options selected, and by post-processing options available.

4.6 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 test method is not intended to supplant the experience and judgment of experts in the field of acoustics. This test method is intended to facilitate communication between sound measurement professionals and individuals who are responsible for administering regulations, or are otherwise involved in decisions involving sound measurements. Measurements shall be performed only under the direction of people 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.

4.7 This test method is only a 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 test method for estimating the influences of two or more simultaneously measured sounds. This test method can be used, with an appropriate plan, 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.

5. Interferences

5.1 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 mentioned briefly in paragraphs 5.1 – 5.8.

5.2 *Effects of Wind:*
5.2.1 Wind may influence sound level measurements, even with a windscreen in place. The windscreen recommended by the manufacturer may not be adequate in quiet environments with mild wind conditions, especially in environments where low frequency, ambient sound must be evaluated. With wind speeds of 20 km/h and a typical windscreen the resulting A-weighted sound level due to the wind alone is 40-45 dB. Wind speeds of 40 km/h result in measured A-weighted sound

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

levels due to wind alone of 60-65 dB. Manufacturers' instructions shall be followed with respect to meter limitations under windy conditions. When wind speeds approach or exceed 20 km/h, headphones shall be used to monitor the sound level meter output or the sound level meter indicator shall be carefully observed to determine if fluctuations correspond to wind speed or actual sound sources. Data obtained during intervals when wind generated sound is influencing the measurements shall not be used. No measurements shall be made when steady wind speeds exceed 20 km/h. Propagation of sound from a source will be influenced by the direction of wind relative to the source and measurement positions. Measurements may need to be taken at different times of the year in different wind conditions to fully identify the acoustical character of the environment.

5.2.2 In special circumstances requiring measurements with wind speeds higher than 20 km/h, such as a background sound level survey involving a wind turbine project, a large (not less than 175 mm) windscreen shall be used. A larger windscreen will produce less low frequency windscreen noise near the microphone. However, it is cautioned, that large, foam type windscreens can cause additional attenuation of high frequency sound. A calibration adjustment may be required. See ANSI S1.17.

5.2.3 If maximum wind speeds are not addressed in the measurement plan, manufacturer's instructions shall be followed with respect to analyzer limitations under windy conditions.

5.2.4 Propagation of sound from a source will be influenced by the direction of the wind relative to the source and measurement positions. In some situations it may be desirable to make such measurements at different times of the year in different wind conditions to fully identify the acoustical character of the environment.

5.3 *Effects of Moisture and High Humidity:*

5.3.1 Measurable precipitation almost always influences outdoor sound levels. For example, tires rolling on a paved surface produce higher sound levels when the pavement is wet. Fallen snow may affect the propagation of sound. Data obtained under such conditions shall be retained but carefully marked so that these data may be used with caution in subsequent analysis.

5.3.2 High relative humidity, generally over 90 %, can influence certain preamplifiers and microphones, especially air-condenser microphones. Microphone manufacturer's instructions shall be followed under high-humidity conditions.

5.4 For sources that emit impulsive sound, the accepted measurement methods for impulsive sound according to ANSI S1.13, such as SEL to quantify individual impulse and time-average sound level to measure periods of time that include impulses, should be used to obtain accurate results. The presence of impulsive sounds emitted by the source under test should be noted in the report. Any measurements in which data (other than a narrative description of the impulses) are obtained should require a prescription for the sampling rate, system response, and other pertinent guidelines including reference to appropriate measurement standards.

5.5 Care shall always be taken to position the microphone away from acoustically reflective surfaces which 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 guidance from a measurement plan, the microphone shall be placed away from any such acoustically reflective surface by at least 2½ times the major dimension of that surface.

5.6 Electromagnetic radiation from high voltage transmission lines or strong television or radio signals may affect the sound level meter indication. The operator should use caution when these are nearby. Such electrical interference problems, when they occur, might result in wild and unexpected swings of the sound level meter indicator or upward indications even when the instrument is turned off. The most effective way to detect these conditions and other anomalies is through monitoring headphones.

5.6.1 Noise from power lines can increase significantly with high humidity, especially during light rain.

5.7 A non-electrical problem related to power lines is the generation of sound by aeolian strumming, or buzzing or rattling by wires which are not tightly secured to insulators near a power line. In a quiet rural environment such sounds can often influence or even dominate the background level. This is an example of a noise source which requires careful consideration when choosing a measurement location. For guidance in determining if such sounds are part of the ambient or constitute interference, determine if the sound is part of the ambient at a point for which the ambient is to be characterized. If it is, it shall be measured. If the sound can be defined as an interference, one which masks an area-wide baseline, the measurement location shall be moved to a point at which the contribution of the source is at a level more representative of its area-wide level. The only way to avoid such interference is to avoid measurement locations close to power poles or lines when the measurement plan does not require a specific location.

5.8 *Effects of Meteorological Conditions:*

5.8.1 Temperature inversions, wind and other meteorological conditions may strongly influence the propagation of sound over long distances. Therefore, when sound from sources at horizontal distances of about 300 m or more need to be measured, it may be desirable to make measurements at different times of the year in different weather conditions to fully identify the acoustical character of the environment.

5.9 *Effects of Wildlife and Insects:*

5.9.1 At various times of the year, naturally occurring sounds from birds, frogs, or insects, including crickets and locusts, may interfere or even dominate the ambient A-Weighted and some fractional octave band sound levels, especially during evening and night hours. Such sounds should be noted in the report. Where possible, an effort may be made to quantify or account for such influence by making measurements at different times or different locations to document conditions with and without such naturally occurring interfering sounds. Octave-band (or ⅓ octave-band) data should be gathered when this is a problem. These data can be used during

post-processing to mathematically remove the effect of the insect noise from the results.

6. Apparatus

6.1 *Acoustical Measurements:*

6.1.1 *Digital Statistical Sound Analysis System,* Use a Type 1 or Type 2 integrating, or averaging sound level meter as defined by ANSI S1.43 and IEC 61672–1, with statistical analysis capability and with a dynamic range of at least 60 dB.. The system shall have one or more of the following capabilities as needed for a specific measurement plan:

6.1.1.1 Selectable exponential time averaging (fast, slow),

6.1.1.2 Ability to be interfaced with a portable computer or programmable calculator which can function as the controller, data storage, or analysis device,

6.1.1.3 Ability to be programmed to perform specific types of measurements and store the data within the analyzer,

6.1.1.4 Computation of values of sound level descriptors, or permanent storage of data for later processing,

6.1.1.5 Weighting filters, that is, A, C,

6.1.1.6 Frequency-domain filters, for example, fractional octave-bands such as 1/1, 1/3 ... 1/n octave, etc.,

6.1.1.7 Ability to compute one or more of various types of sound level, that is, the percentile level, (L_X) or the time–average sound level (L_{AT}) also called equivalent sound level (L_{EQ}) for the measurement period, and

6.1.1.8 Ability to identify the occurrence of sound-level events which exceed some level threshold and provide data on the time and duration of occurrence, and sound level during the event, including generation of histograms of the number of occurrences, or durations, that sound levels exceed selected thresholds.

6.1.2 *Outdoor Microphone System (required)*—At a minimum, the outdoor microphone system shall consist of the following:

6.1.2.1 Microphone and preamplifier recommended by the manufacturer of the measurement instrument, and compatible with and supporting the ANSI Type 1 or Type 2 requirement of the sound level meter portion of the system. The microphone shall also meet the measurement plan requirements for frequency response, directional response, and internal background noise (self noise).

6.1.2.2 The windscreen recommended by the manufacturer may not be adequate in quiet environments with mild wind conditions. See 5.2.1 and 5.2.2.

6.1.3 The microphone system shall include the following features as appropriate for the time duration and conditions expected during the measurement;

6.1.3.1 Microphone and preamplifier system that (*a*) does not experience a significant sensitivity- or frequency-response change caused by humidity effects, or (*b*) can be used with an appropriate desiccant system prescribed by the manufacturer,

6.1.3.2 *Microphone Rain Shield.*

6.1.3.3 *Tripod,* of the type normally used for supporting photographic equipment, a mast integral with the instrument shelter, or other support sufficiently strong to support the weight of the microphone and protective equipment mounted on it, and which by virtue of its weight or attachment to the ground is resistant to being upset by the wind or other disturbances,

6.1.3.4 *Bird Deterrent Accessory,* known as a *bird spike*, used to prevent fouling of windscreens by roosting birds. It is recommended that a bird-deterrent accessory, available from some microphone manufacturers, be installed on the windscreen.

6.1.4 *Acoustical Calibrator (required),* with adapters necessary to fit the microphone, meeting ANSI S1.40.

6.1.5 *Headphones*—Headphones for monitoring the a-c output of the sound level meter portion of the analyzer shall have the ability to exclude external sound. The headphones, with an appropriate battery-powered driver, shall have sufficient frequency response to permit detection of anomalies in the data caused by wind, humidity, and electrical interference. A frequency response of 50 to 20 000 Hz should be adequate. The headphones shall be correctly matched to the source impedance of the output terminals.

Warning—Exercise care when using headphones with sound level meters since some meters and headphones are not compatible without the use of an impedance matching amplifier. Failure to use such an amplifier, when needed, may damage the meter, or cause the meter to produce inaccurate results. If it is necessary to modify the circuits of an instrument in order to use headphones, it shall be done by, or under guidance from, the instrument manufacturer. A thorough functional check and calibration shall be performed by qualified technicians before using the instrument.

6.1.6 When there is a likelihood of adverse conditions, an environmental enclosure capable of protecting the critical components of the measurement instruments (other than the microphone) from physical damage, keeping them dry and at a temperature within the manufacturer-recommended operating range. (See 6.1.3.2 regarding protection for the microphone.)

6.2 *Physical Measurements:*

6.2.1 To ensure an accuracy of 1 dB in values obtained from calculations that include the results of distance measurements, the accuracy of the distance measurements to be used in calculations must be within 5 %. A Global Positioning System (GPS) or any technique that provides this degree of accuracy is satisfactory. If the data are to be used for modeling, and if the study area is undulating in nature, and the variation in elevation exceeds 2 m it is recommended that a topographical map be consulted for estimating elevation of sound sources, potential receptors, and potential acoustical barriers.

6.2.2 *Direction*—A pocket compass should be used for site layout work and a wind vane capable of measuring wind direction in octants should be used for determination of wind direction used for site layout work and determination of wind direction.

6.2.3 *Site Map*—If it is not included in the measurement plan, it is recommended that a site map be acquired or prepared prior to starting measurements.

6.3 *Meteorological Measurements:*

6.3.1 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.

6.3.2 For certain types of calibrators barometric pressure must be observed at the time of calibration. In some cases radio reports of meteorological conditions can be useful; however, it is preferable to use available general accuracy meteorological instruments to enable the measurement of:

6.3.2.1 Wind speed (5-km/h increments),

6.3.2.2 Wind direction to the nearest of the eight common compass directions,

6.3.2.3 Relative humidity (in 10 % increments),

6.3.2.4 Dry bulb temperature (in 2°C increments), and

6.3.2.5 Barometric pressure as specified by the (acoustic) calibrator manufacturer if required for the proper use of the calibrator. The absolute pressure is needed, not the pressure corrected to sea level as reported by the weather bureau.

6.4 *Photographs*—A camera, shall be carried by the measurement team for the purpose of documenting the equipment setup and surroundings at least once at each measurement location.

7. Calibration

7.1 Verify the calibration of the sound level meter portion of the system using a portable acoustical calibrator immediately before and after each continuous run of the analyzer in a manner prescribed by the manufacturer. If measurement data stored by the analysis system are to be transferred to magnetic media, store and transfer at least one of the periodic calibration data sets to a calibration file on media separate from data files. In all cases, enter the calibration data in the official handwritten field log at the time of calibration. (See 8.5.)

7.2 During a series of related measurements, after initial calibration adjustment, make no further adjustments to the instrument to make the calibration indication agree with the expected value, unless required by the measurement plan. Instead, use the calibration record to standardize the data during subsequent data reduction and analysis. If the measurement plan requires manipulation of the calibration control during the measurement program, maintain a record of calibration adjustments over the course of the measurement campaign. Record the time(s) at which calibrations were performed and the instrument calibration indication before and after each adjustment. If the change in the indication exceeds ½ dB, mark the data in a way that will call attention to the change. If the change is 1 dB or greater, investigate the cause of the change and replace suspect components of the system to the extent possible, in an attempt to isolate the problem in a manner consistent with the measurement schedule. Discuss any change of 1 dB or greater in the measurement report. It is strongly recommended that an instrument that shows an unexplained calibration drift greater than 1.5 dB over 24 h or less be taken out of service until the cause of the drift can be identified and remedied. Also, verify calibration if the sound level meter or microphone is abused (dropped, wet, etc).

7.3 Within one year, or a period specified by the measurement plan, prior to starting the measurements, verify all equipment specifications claimed by the manufacturer using standards traceable to a recognized standards organization, and following recommendations of the instrument manufacturer. These checks shall include the instrument, microphone and preamplifier, and filters (if used).

7.3.1 Thoroughly calibrate the acoustical calibrator following recommendations of the instrument manufacturer, as specified in the preceding paragraph.

7.4 Measure the self-noise of the measurement system, including the microphone and microphone preamplifier system, with all connecting cables in the system, before starting measurements and at least daily, thereafter, until the measurements are complete, to verify that the self-noise is less than the lowest level to be measured.

7.4.1 Measure the self-noise by covering the microphone with a suitable acoustic isolator and recording the indicated sound level.

7.4.1.1 To be effective the isolation device used shall provide isolation at all frequencies of interest. The level reduction in each fractional band of interest should be sufficient to assure that the instrument noise is at least 10 dB below the lowest level of interest.

7.4.1.2 If a suitable acoustic isolator is not available, perform the measurement by temporarily replacing the microphone cartridge with a dummy microphone recommended and approved by the microphone manufacturer, recording the indicated sound level(s). To the indicated sound level(s), add the typical microphone self-noise values provided by the manufacturer of the microphone.

7.4.2 When fractional-band measurements are being performed, check the self-noise in each band at least weekly, or at intervals called for in the measurement plan.

7.4.2.1 It is recognized that obtaining an effective isolation device may be difficult.

7.4.3 If it is not possible to demonstrate ability to measure to the necessary lowest level, either because of an actual instrument self-noise, or because of an isolation device having sufficient sound level reduction is not available, clearly mark any subsequent data recorded to reflect the fact that actual sound levels may, at times, be lower than those recorded. The cautionary statement shall, if practical, include an estimate of the self-noise, and a statement concerning the effect it would have, in terms of the difference between the indicated lower levels and the actual lower levels.

8. Procedure

8.1 *Selecting Measurement Locations and Times*—When acquiring sound-level data, select locations and times for measurements consistent with the reason for making the measurements and the manner in which the results will be used.

8.2 *Location Descriptions*—A location description prepared as part of a measurement plan can be used for this purpose, otherwise prepare a detailed written description of the location. Describe the location in terms of its relation to permanent landmarks. List and give distance and bearing to structures, roads, and other identifiable noise sources that are within 1000

m of, and visible from, the site. Photographs are recommended, as are USGS or other satellite imagery, topographic maps, site plans, etc.

8.3 *Preparation of Equipment*—Prepare the measurement and analysis system according to manufacturer's instructions. Preparation shall include the following steps:

8.3.1 Check the battery condition before and after a continuous measurement and record the condition on the data sheet.

NOTE 1—Make certain that the useful charge is sufficient to complete the planned measurement. Consult the manufacturer of the equipment for information on battery life and the use of auxiliary battery packs.

8.3.2 Verify calibration of the sound measuring equipment in accordance with manufacturer's instructions.

8.3.3 Replace the wind screen(s) and any other items removed for calibration.

8.3.4 At least once each day, more often in wet weather and when measurements are continued over more than an 8-h period, verify that any system which is intended to keep the microphone and preamplifier dry is functioning properly.

8.3.5 Select the weighting and filter bandwidths as outlined in the measurement plan. If no guidance is available, it is recommended that at least one analysis channel be used for A-weighted sound level.

8.3.6 Set the averaging time and sample rate as called for in the measurement plan.

8.3.7 Set the measurement duration, dynamic range, and maximum range at values appropriate for the measurement situation. Consider 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. Include the choice and the rationale in the measurement plan, and document in the field log. Include with this information the manner in which the instrument documents an out-of-range measurement.

8.3.8 *Protection of Equipment:*

8.3.8.1 Provide protection for the analyzer against rain and solar heating as necessary, especially if measurements will involve a substantial time period. Consult the manufacturer's specifications for acceptable ranges of temperature and humidity, and take steps to maintain the equipment environment within these ranges, recognizing that solar heating could increase equipment temperature above ambient air temperature.

8.3.8.2 Obtain any microphone cable needed to allow proper placement or sheltering of equipment from the manufacturer of the equipment, or meet the manufacturer's specifications. Tests shall be performed to determine that the cable meets manufacturer's specifications, and that the microphone system and cable perform satisfactorily over the range of sound level and frequency to be measured.

8.3.8.3 If it is necessary to use a vehicle as a shelter for both the operator and equipment, take extreme care to avoid acoustical or electromagnetic interference as well as wind turbulence effects. In this case locate the microphone as far away from the vehicle as a 30-m microphone cable will allow. At a minimum, the distance shall be at least 2½ times the largest dimension of the shelter vehicle.

8.3.9 Unless specified differently by the measurement plan, support the microphone on a sturdy tripod or mast at a height between 1.2 m and 1.5 m above the ground. In general, avoid placing the microphone tripod on a surface that is not typical of the locale, or in tall grass (in excess of 0.25 m). 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.

8.3.10 Following the guidance of the measurement plan or the microphone manufacturer's recommendation, orient the microphone properly with respect to the source of the sound to be measured.

8.4 *Conducting the Measurement*—Having completed the preparations called for in 8.1 – 8.3, if the analyzer controls permit, start the measurement remotely, or set the analyzer to start the analysis after a 1 or 2-min delay. This will allow time for the operator to move away from the microphone and complete any noisy operations before the measurement starts. If the delay feature is not available, avoid making extraneous sound in the vicinity of the microphone after starting the measurement.

8.5 *Maintaining a Log*—During the measurement make a written record, preferably using a pre-printed data entry form, of any necessary data relevant to the specific measurement which is not printed by the measurement system or previously recorded. Include the following information.

8.5.1 *Location Information*—A brief description (one or two hand-written lines will suffice) of the location which will positively associate the location with the description prepared in accordance with the instructions in 8.2. If a formal sampling plan is being followed, use the name or code assigned to the location by the plan.

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

8.5.3 Information sufficient to identify the manufacturer, model, serial number (where applicable), and the last laboratory calibration (where applicable), for the following acoustical instrumentation system components, when used:

8.5.3.1 Analyzer or sound level meter,

8.5.3.2 Microphone,

8.5.3.3 Outdoor microphone system,

8.5.3.4 Microphone cable, and

8.5.3.5 Calibrator.

8.5.4 *Environmental Conditions*—Record environmental conditions representative of the measurement set. The information recorded shall include the following:

8.5.4.1 Temperature,

8.5.4.2 Relative humidity,

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

8.5.4.4 Wind speed (range if appropriate),

8.5.4.5 Wind direction (direction blowing from) in octants (N, ENE, ... WNW) or multiples of 45° (0, 45, ... 315),

8.5.4.6 Sky condition, for example, clear, scattered clouds, partly cloudy, mostly cloudy, overcast, and

8.5.4.7 Ground condition, for example, dry, dew, wet, snow.

8.5.4.8 Record the conditions 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, measure wind direction and speed and record more frequently, for example, at intervals of no more than 15 min.

8.5.4.9 If the wind speed is close to the threshold at which measurements should be suspended, wind speed shall be monitored continuously.

8.5.5 *Traffic Count*—Some measurement plans require making a record of traffic count, especially if traffic is the dominant source of interest or a significant interference with another source of interest. Keep a record according to the instructions of the measurement plan.

8.5.6 *Major Sound Sources*—Identify major contributing sound sources and record the distance from each source to the measuring location (see 6.2.1).

8.5.7 *Comments*—Provide brief narrative comments, as necessary, including:

8.5.7.1 Any unexpected or unusual sound sources which need to be considered in evaluation of the data. Examples in various situations could be aircraft overflights, railroad operations, barking dogs, or other animal sounds.

8.5.7.2 Unusual weather conditions, especially thunder.

8.5.7.3 Any pertinent observations such as that acoustical propagation conditions are different from those expected, correlation between wind direction and direction of unexpectedly loud or quiet distant sounds, and subjective estimates of the relative loudness of distance sources compared to nearby sources. This information can facilitate the evaluation of the effect of meteorological conditions on sound propagation.

9. Report

9.1 Report the following information:

9.1.1 All pertinent data prescribed by the measurement plan and collected during the measurement, including:

9.1.1.1 A tabulation showing the results of each measurement set (to the number of decimal places consistent with requirements of the study and the capability of the measurement system), with identification of locations, date, time, and duration of each measurement set.

9.1.1.2 A description of measured sounds (steady, tonal, impulsive), repetition rate of impulsive sounds, and the identified or suspected sound sources.

9.1.1.3 A description of circumstances concerning lost data, that is, interrupted samples, loss of power, etc, with an estimate of the effect on data integrity.

9.1.2 *Information on analyzer settings:*

9.1.2.1 Range,

9.1.2.2 Analysis bandwidths and weightings,

9.1.2.3 Sampling rate,

9.1.2.4 Detector response time or averaging time, and

9.1.2.5 Analysis system self-noise at the range used.

9.1.3 *Calibration*—In addition to a description of the calibration method, describe any problems with calibration, that is, unusual requirements to readjust system calibration.

9.1.4 *Meteorological Conditions*—Report meteorological conditions for each measurement set. It is recommended that this data be included in the tables showing the results of the measurement sets. If field notes show conditions were stable throughout several measurement sets, a single statement of the conditions will suffice.

9.1.5 *Site Descriptions*—This may be done by referencing and including the measurement plan. If there is no measurement plan, a written description shall be prepared, including a map showing the microphone location, as well as distance, direction, and estimated height of structures and vegetation within 100 m of the microphone.

9.1.6 *Instrumentation Information*—Manufacturer, model, and, where appropriate, serial number and date of last laboratory calibration for the following:

9.1.6.1 Analyzer,

9.1.6.2 Microphone,

9.1.6.3 Outdoor microphone system, and

9.1.6.4 Calibrator.

9.1.7 Names, business addresses, and phone numbers of the persons making the measurements.

9.1.8 A statement, to the extent true, that this test method was followed. Any exceptions shall be noted and reasons given.

9.1.9 It is recommended that all field notes or log sheets, whether or not included with the report, be retained for future reference.

9.1.10 A brief description of conditions existing at the time of the measurement, relative to past or future long-term conditions, that is, is this a measurement of the baseline ambient condition, a perturbed condition, or a random sample.

10. Precision and Bias

10.1 The precision of the data obtained using this test method is a function of the instrument used, analysis parameters selected, and the range of sound levels measured. In general, if the number of samples in a set or subset of data is at least 10 times the range of the measured data in the set or subset, the precision for the result of the set or subset will be better than plus or minus 2 dB.

NOTE 2—As an illustration, assume an analyzer with a sampling rate of 20 samples per second per band. A set of averages stored every 15 s would contain 300 samples per average in each band. If the range of the samples is not more than 30 dB, each stored average would have a precision of at least plus or minus 2 dB because the number of samples is ten times the range of the samples.

NOTE 3—This precision applies only to the specific measurement period and not to any degree to which that period might be representative of a longer period of time.

10.2 Bias is limited to the accuracy of the acoustical instruments.

11. Keywords

11.1 acoustical environment; analysis; calibration; community noise; data storage; digital; equipment; interferences; loudness; measurement; measurement plan; meteorological

effects; microphone system; outdoor; precautions; procedures; sound level; statistics; supporting data

APPENDIX

X1. PREPARING A MEASUREMENT PLAN FOR CONDUCTING OUTDOOR SOUND MEASUREMENTS

X1.1 Scope

X1.1.1 This appendix addresses the preparation of a measurement plan to document outdoor sound levels. A detailed plan is useful for major environmental noise studies requiring numerous measurements at several locations over a long period. This Appendix is intended primarily for use in such cases. However, even simple measurements can benefit from a brief, generic plan.

X1.1.2 On occasion, a need to depart from the normal measurement methodology may arise, in order to accommodate a special situation or a regulatory requirement. This Appendix provides options that are technically correct for specific situations and provides the information needed for selecting options.

X1.1.3 Measurements that may be planned using this appendix include, but are not limited, to the following:

X1.1.3.1 Measurement of low-frequency sound (infrasound) is included because it can cause structural vibration that translates to audible interior sound.

X1.1.3.2 Measurement of impulsive sound.

X1.1.3.3 Measurements of sound with significant tonal content.

X1.2 Significance and Use

X1.2.1 This appendix 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.

X1.2.2 This appendix outlines procedures for making and documenting the physical observations necessary to qualify the measurements.

X1.3 Recommended Report Format

X1.3.1 *Scope of Measurement*—A clear statement of the scope to provide an appropriate opening statement for the measurement plan. The following basic information should be contained in the scope:

X1.3.1.1 *Identification of Client*—The name and address of the organization or person for whom the measurements are to be made.

X1.3.1.2 *Reason for Measurements*—The reason for performing the measurements, carefully described in a way that provides guidance in defining the measurement process.

X1.3.1.3 *Type of Analysis Required*—The type of analysis planned for the data obtained.

X1.3.2 *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.

X1.3.2.1 *Map of the study area*——Measurement locations should be identified on the map by appropriate code numbers or letters.

X1.3.2.2 *Aerial Photograph*—An aerial photograph, at the same scale as the map of the study area, may be useful to provide added detail of the site

X1.3.3 *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 should be communicated separately from the plan.

X1.3.4 *Regulatory Information*—If the measurement is required by, or results of the measurements will be reviewed by, a regulatory agency, include regulatory information.

X1.3.5 *Non-Regulatory Information*—There may be occasion where non-regulatory information is considered in the study. For example, criteria may be established by the project which are more restrictive than regulatory limits. Any such criteria should be noted.

X1.3.6 *Time Period Covered*—Describe the time period over which the measurements are to be made. Include any specific requirements to document sound levels associated with specific activities in progress, or when certain atmospheric conditions prevail.

X1.3.7 *Selection of Measurement Locations*—This section provides the measurement locations to be used. If the measurements are to be used to characterize the acoustic environment of a point, zone, district, or enclave, the measurements locations must be validated in a manner that ensures a degree of spatial resolution necessary to adequately, and appropriately do this. (See also ANSI S12.9, Parts 2 and 3.)

X1.3.8 *Instrumentation*—Provide a description of all measurement equipment utilized, including:

X1.3.8.1 Manufacturer and model number,

X1.3.8.2 Serial number, and

X1.3.8.3 Date of last calibration.

X1.3.9 *Field Procedures*—Outline field procedures for the measurements and the rationale behind the decisions. See also X1.6.

X1.3.10 *Reporting Plan*—Define the type and frequency of reporting and indicate the data that should be submitted

X1.3.11 *References*—Cite any references used.

X1.4 Equipment Requirements and Specification

X1.4.1 This section provides guidance in using the measurement scope to determine minimum requirements for sound measurement equipment for performing the noise measurements and for physical measurements associated with the sound measurements. Any equipment that meets the minimum requirements may be used, provided that the features required to satisfy the requirements of the scope are considered in setting up the measurement plan.

X1.4.2 *Microphones*—Microphone characteristics of concern in optimizing a measurement system for a particular situation are the following:

X1.4.2.1 frequency response,

X1.4.2.2 directional response, and

X1.4.2.3 self noise.

X1.4.3 *Frequency Response*—The microphone selected for the measurements should have a nominal frequency response range that includes the range of frequencies called for in the scope of measurements.

X1.4.4 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.

X1.4.5 *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) 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.

X1.4.6 *Microphone Self Noise*—Microphone self-noise may constitute an interference in the measurement of sound levels. This element must be considered in the selfnoise of the total measurement system. (See also X1.4.11.2)

X1.4.7 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.

X1.4.8 *Microphone Windscreen*—Use of a microphone windscreen system, compatible with the microphone system and suitable for the conditions under which measurements are to be made is required. In selecting a windscreen, the recommendations of the microphone manufacturer, and the specifications of the windscreen should be considered.

X1.4.9 If available, the published wind-noise spectrum of the installed windscreen should be compared with the spectrum of expected measured sound levels to estimate the influence of the windscreen on the measured sound data.

X1.4.10 *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, although many modern microphones are less sensitive to humidity than traditional air-condenser microphones. If it is established that the system microphone needs to be protected from moisture/humidity, 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 should 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.

X1.4.11 *Precision, Accuracy, and Calibration*—There are two areas in which precision and accuracy considerations apply: measuring of sound level and accurately establishing locations (distance measurement). At a minimum, the plan should require the following procedures related to precision, accuracy, and calibration.

X1.4.11.1 *Field Adjustments of Sound Measurement Equipment*—It is highly desirable that during a series of related measurements, after initial calibration adjustment, no further adjustments should be made to the instrument. Instead, the calibration record should be used to standardize the data during subsequent data reduction and analysis. However, if there is some legitimate reason to manipulate calibration control during the measurement program, a record should be maintained of calibration adjustments over the course of the measurement. The record should be retained with the field notes.

X1.4.11.2 *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 as 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.

X1.4.11.3 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 should require a check of the broad-band self noise at appropriate intervals.

X1.5 Measurements

X1.5.1 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

should take these factors into consideration. The locations should be selected to:

X1.5.1.1 Be representative of the area or location to be studied,

X1.5.1.2 Represent a boundary condition,

X1.5.1.3 Represent a sensitive receiver location, and

X1.5.1.4 Reference location near a machine being examined.

X1.5.1.5 Not be influenced by other interferences. Occasionally naturally occurring factors may be perceived as an interference, perhaps seasonally. If these sounds are representative of the character of the sound at a particular location, they should be included. (See 5.9.)

X1.5.2 *Equipment Settings*—The plan should include control settings (or ranges of settings) for all measurement, analysis, and recording equipment. If a regulatory Noise Code compliance is being documented, the measurement parameters must be consistent with the Code requirements.

X1.5.3 *Averaging Time and Sampling Rate*—Set the meter time weighting as called for in the governing document.

X1.5.4 *Measurement Duration, Dynamic Range, Maximum Level*—Set the measurement duration, dynamic range, and maximum range at values appropriate for the measurement situation (that is: refer to Guide E1686 for guidance). 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 should 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. Many newer instruments have a very wide dynamic range and no range adjustments will be needed.

X1.5.5 Select measurement locations using the following process:

X1.5.5.1 Evaluate the extent of the study area.

X1.5.5.2 Identify points within the study area at which measurements are needed.

X1.5.5.3 Evaluate the potential for interference at each location. If the interference is a naturally occurring factor, it should be considered part of the environment and included in the measurements (See 5.9) If the interference is not typical throughout the study site (See 5.6 and 5.7), consideration should be given to minimizing its influence on the measured sound levels. If necessary, adjust the location to avoid, or minimize, the interference.

X1.5.6 *Schedule and Duration of Measurements*—This section provides guidelines for establishing a sampling sequence 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.

X1.5.7 *Temporal Changes*—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. It is important that the investigator be aware of the potential for changes in ambient sound production because of changes in meteorological conditions. The plan should require documentation of the occurrence of such a change. The plan should 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. The following subsections provide guidance in setting up a measurement schedule that will adequately sample these cycles.

X1.5.7.1 *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.

X1.5.7.2 *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.

X1.5.7.3 *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 5.8.)

X1.5.7.4 *Unattended Measurements*—It is strongly recommended that, for unattended measurements, events exceeding an established threshold are documented with a short recording. Many sound level meters now have this capability. An exception would be measurements involving only the determination of the sound level exceeded 90 percent of the time $L_{(90)}$. In this case, the analysis process strips away most of the interference related to spurious sound sources.

X1.6 Field Procedures

X1.6.1 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 created. Survey site plans and digital maps may be useful in determining locations. When alternative actions are anticipated the rationale for selection of a particular option, based on circumstances, should be included in the plan.

X1.6.2 *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 as follows:

X1.6.2.1 with the local noise source silent in order to assess its effect on the local receptors, and

X1.6.2.2 at increased distances to identify the region of influence of the source.

X1.6.3 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.)

X1.6.4 *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.

X1.6.5 *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.

X1.6.6 *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.

X1.6.7 *Microphone Placement*—Unless there is a requirement to place the microphone at a specific location, or if special circumstances prevail, it is general practice to support the microphone on a sturdy tripod or mast at a height between 1.2 m and 1.5 m above the ground. 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, should be described on the data sheet and in the report. If it is not possible, because of local conditions, to follow these requirements, this should be stated on the data sheet and in the report.

X1.6.7.1 *Precautions*—The plan should contain the following precautionary statement: "Care should 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 2 ½ times the major dimension of that surface."

X1.6.7.2 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.

X1.6.7.3 At a minimum the plan should follow the microphone manufacturer's recommendation for orientation.

X1.6.7.4 If the measurements are intended to represent all of the sound in the area surrounding the microphone, the preferred microphone is a random incidence microphone with the diaphragm in the horizontal plane. If the measurements are intended to represent the sound from a specific source, the preferred microphone is a free-field direct-incidence microphone with its axis pointed at the source. An alternative, in this case, is to use a random-incidence microphone oriented so that there is a 70° angle between the cylindrical symmetry and a line connecting the source location and the microphone location.

X1.6.7.5 When measuring aircraft noise, the location of the microphone relative to the flight path and type of microphone should be considered. If the microphone is directly below the flight path, a free-field direct-incidence microphone pointed upward would be preferable. Otherwise a random-incidence microphone would be preferable.

X1.7 Special Types of Sound

X1.7.1 The plan should include guidance for situations in which the sound to be measured is characterized by impulses, tones, or infra-sound.

X1.7.2 Special measurement methods are required to quantify the sound levels of individual impulses. These may involve peak levels with a true peak reading instrument, or a sound exposure level. Any criteria to be used to evaluate such sound should be established prior to measurements to assure the measurements are made appropriately. See ANSI S1.13 for guidance.

X1.7.3 *Tonal Sounds*—When the presences of tones is obvious or anticipated fractional-band analysis (for example 1/3 octave band or finer) should be included in the measurement. If, in the judgment 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 should be made to, in the judgment of the investigator, characterize the temporal as well as the spectral nature of the tones.

X1.7.4 *Low-Frequency Sound*—Measurements of low frequency sound levels can vary considerably over even very

short distances. Point measurements may not represent the sound levels throughout their immediate neighborhood.

X1.8 Supporting Data

X1.8.1 The plan should 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. Sound data is typically stored in the instrument. The data sheet is intended to clarify the conditions and locations of the measurements. Documentation should include the following information and data:

X1.8.1.1 *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.

X1.8.1.2 *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 should be stated.

X1.8.2 *Concurrent Traffic Survey*—If analysis of the measurement results includes correlation of traffic data with sound level data, the plan should 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 should specify the format of the record and state the discriminants for vehicle type. Typical discriminants would include one or more of the following:

X1.8.2.1 Passenger cars and light trucks,

X1.8.2.2 Medium trucks and vans, and

X1.8.2.3 Heavy trucks.

X1.8.3 *Environmental Conditions*—Record environmental conditions that are representative of the time period for each measurement set. The information recorded should include the following:

X1.8.3.1 Temperature,

X1.8.3.2 Relative humidity,

X1.8.3.3 Barometric pressure (and altitude, if required for microphone calibration),

X1.8.3.4 Wind speed (range if appropriate),

X1.8.3.5 Wind direction (direction blowing from) in octants or multiples of 45 degrees,

X1.8.3.6 Sky condition, that is, clear, scattered clouds, partly cloudy, mostly cloudy, overcast, and

X1.8.3.7 Ground condition, that is, dry, dew, wet, snow.

X1.8.3.8 Conditions should 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.