



Designation: E 1780 – 96

## Standard Guide for Measuring Outdoor Sound Received from a Nearby Fixed Source<sup>1</sup>

This standard is issued under the fixed designation E 1780; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### INTRODUCTION

This is one of a series of standards and guidelines for measurement and evaluation of community noise. Also in preparation is a standard method for preparing a measurement plan and a guide to determine the validity and significance of outdoor noise measurement data. Techniques and precautions in this guide are not fixed or mandatory and cannot replace the judgment of acoustical professionals. Rather, this guide is a summary of processes found to be productive and useful in ensuring that meaningful information will be gathered in an efficient manner about fixed sources of noise in a community as they each may exist. Others in this series include Guide E 1014, which covers manual A-Weighted measurements of outdoor noise using a simple meter, and Test Method E 1503. ANSI 12.18 provides a method of obtaining repeatable sound pressure level measurements of the sound emitted by a source. This document differs in that atmospheric and ground effects are not controlled. Thus, the results may not repeat if atmospheric conditions or ground conditions between the source and the measurement position change. This guide provides only a method of accurately documenting the sound levels occurring at the measurement position at the time of measurement.

### 1. Scope

1.1 This guide covers the measurement of outdoor sound due to a fixed sound source such as a siren, stationary pump, power plant, or music amphitheater. Procedures characterize the location, sound level, spectral content, and temporal characteristics of that sound source at the time of measurement. Users should be aware that wind and temperature gradients can cause significant variations in sound levels beyond 300 m (1000 ft). With appropriate caution, the use of measurements resulting from this guide include but are not limited to:

- 1.1.1 Assessing compliance with applicable regulations,
- 1.1.2 Monitoring the effectiveness of a noise reduction plan,
- 1.1.3 Verifying the effectiveness of measures for mitigation of noise impact,
- 1.1.4 Validating sound prediction models, and
- 1.1.5 Obtaining source data for use in sound prediction models.

1.2 This guide may be used according to Guide E 1779 and specified in the measurement plan.

1.2.1 This guide can also be used to conduct measurements without a plan provided an operator/observer whose qualifica-

tions are satisfactory to both the performing organization and the user of the results is present at all times during the measurements and who complies with the applicable requirements of this guide, including record keeping.

1.3 *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<sup>2</sup>
- E 1014 Guide for Measurement of Outdoor A-Weighted Sound Levels<sup>2</sup>
- E 1503 Test Method for Conducting Outdoor Sound Level Measurements Using a Digital Statistical Analysis System<sup>2</sup>
- E 1779 Guide for Preparing a Measurement Plan for Conducting Outdoor Sound Measurements<sup>2</sup>

#### 2.2 ANSI Standards:<sup>3</sup>

- S1.4 Specification for Sound Level Meters
- S1.11 Octave-band and Fractional Octave-band Analog and

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 04.06.

<sup>3</sup> Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

- 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
- S12.14 Sirens
- S12.18 1994 American National Standards Procedures for Outdoor Measurement of Sound Pressure Level
- 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

### 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 the line-of-sight between the fixed source under test and the measurement microphone that may reduce or otherwise interfere with the passage of sound from the fixed sound source to that microphone.

3.2.2 *dummy microphone*—a microphone substitute which has electrical characteristics identical to a functional microphone, but which is not sensitive to incident acoustic energy. It is used in place of a functional microphone when evaluating the internal noise of an acoustic measuring system.

3.2.3 *equivalent sound level,  $L_{eq}$* —see *time-average sound level*.

3.2.4 *fixed source*—any permanently installed equipment capable of emitting sound on a regular basis such as a pump, power station or warning siren, sound amplification system permanently installed or stationary for a concert.

3.2.5 *impulse sound*—a brief, intrusive sound, such as that emitted by impacting metal objects, operation of a punch press or the discharge of a firearm. (See ANSI S1.13.)

3.2.6 *interference*—any activity or event occurring near the measurement location that could produce anomalous measurement results or data which are not representative in the context of the measurement objectives. Examples are air turbulence generated by the wind at the microphone, people or animals making sounds in the vicinity of the microphone, or the presence of surfaces which alter the normal sound propagation path. See Appendix X2 for additional details and precautions.

3.2.7 *measurement plan*—a document covering requirements unique and specific to the objectives of the measurement including selection of sound measurement times and locations, number and length of measurement sets, and directions on actions to be taken in case of major changes in environment while obtaining a measurement set. See Section 8.

3.2.8 *measurement set*—the set of acoustical and related data results obtained at a single measurement location during a specific time period. The time of measurement should be selected based on the purpose of the measurement as specified

in Section 8, with due consideration for a specific source operating condition and one or more sound propagation conditions.

3.2.9 *noise floor*—see *self-noise*.

3.2.10 *percentile level*—the sound level exceeded during a specific percent of time in a measurement set. (Also known as percentile exceedance level.)

3.2.11 *self-noise*—extraneous signal components, not part of the sound field to be measured, generated or induced in a measurement system which set the lower limit or floor below which accurate measurements cannot be made. See Terminology C 634, definition of background noise.

3.2.12 *time-average sound level*—the value obtained by integrating and averaging an A-weighted sound level measured over a specific period of time, or in the case of unweighted (flat) sound pressure and fractional octave bands, time average sound pressure level. (Also known as equivalent sound pressure level.) See Terminology C 634, definition of average sound pressure level.

### 4. Significance and Use

4.1 Situations for which outdoor sound level data are required include, but are not limited to, comparison of sound levels with criteria or regulatory limits.

4.2 This guide provides information to (1) measure outdoor sound level in the vicinity of outdoor fixed noise sources, and (2) document other observations necessary for the measurements. This guide provides a standard procedure for a trained acoustical professional that will produce results and documentation which are consistent with the purposes cited in 1.1.1-1.1.5.

4.3 These sound measurements should be performed by or under the direction of a person experienced in the measurement and analysis of outdoor sound, and who is familiar with the use of the required equipment and techniques.

4.4 This guide can be used by individuals, regulatory agencies, or others as a measurement guide to collect data on the sound level received from a fixed source within the constraints cited in 8.1 and Appendix X2.

4.5 This guide can be used to establish compliance or noncompliance at the time, distance, and conditions during which the data were obtained. However, this guide is only a measurement procedure and does not address the problem of projecting the acquired data outside those conditions, other times of day, other distances, or comparison with specific criteria. In particular, for a given sound source level, distant noise levels will often be found to be greater at night than during the day.

### 5. Apparatus

5.1 *Acoustical Measurements:*

5.1.1 Use a Type 1 or Type 2 sound level meter as defined by ANSI S1.4 and with a dynamic range of at least 60 dB. The instrument should have a buffered AC signal output port to permit the use of headphones. If measurements are to be made in fractional octave-bands, the system should include filter sets that fulfill the objectives of the measurement plan. Filters should meet the requirements of ANSI S1.11.

5.1.2 *Outdoor Microphone System*—At a minimum the outdoor microphone system should consist of the following:

5.1.2.1 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 should also meet the measurement requirements for frequency response, directional response and internal background noise (self-noise).

5.1.2.2 Microphone windscreen compatible with the microphone system and meeting the requirements of the measurement plan and the weather conditions under which measurements are made.

5.1.3 The microphone system should include the following features as appropriate for the time duration and weather conditions expected during the measurement set.

5.1.3.1 Microphone and preamplifier system that does not experience a sensitivity or frequency response change beyond ANSI Type 1 or Type 2 limits caused by moisture and temperature effects during the course of the measurement.

5.1.3.2 Microphone rain shield for use when applicable.

5.1.3.3 A tripod of the type normally used for supporting photographic equipment, a mast, or other support sufficiently strong to support the weight of the microphone, possibly the sound level meter and attached protective equipment.

5.1.3.4 To prevent fouling of windscreens by roosting birds during long term and unattended measurement, it is recommended that a bird repellent device, known as a “bird spike” be installed on the windscreen.

5.1.4 Acoustical calibrator (required), with adapters necessary to fit the microphone.

5.1.5 *Headphones (recommended)*—Headphones for monitoring the AC output of the sound level meter portion of the analyzer should have the ability to exclude external sound and prevent sound from the earphones from reaching the measurement microphone. The headphones, with an appropriate battery-powered driver, should have sufficient frequency response to permit detection of anomalies in the data caused by wind, humidity, and electrical interference. A frequency response of 50–20 000 Hz is adequate. The headphones or other load should be correctly matched to the source impedance of the sound level meter AC output port.

**NOTE 1—Caution:** Headphone impedance may not be compatible with the AC output port of some sound level meter instruments. An impedance matching amplifier (buffer) may be required. Failure to use such an amplifier, when needed, can cause the meter to produce inaccurate results. If the sound level meter circuit is modified to use headphones, a functional check and calibration of that sound level meter must be performed by a qualified technician before using that instrument.

5.1.6 When there is likelihood of rain, extreme heat or humidity, or of extreme cold conditions, an enclosure capable of protecting the critical components of the measurement instruments from causing measurement error should be provided. (See 5.1.3.2 regarding protection for the microphone.)

## 5.2 Physical Measurements:

5.2.1 *Distance*—The accuracy of the distance measurements to be used in calculations must be within 5%. 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 (6 ft), it is recommended that a topographical map be consulted for estimating elevation of sound sources, potential receptors, and potential sound barriers.

5.2.2 *Direction*—A pocket compass should be used for site layout work and determination of wind direction within 45 degrees.

5.2.3 *Site Map*—A scale map of the measurement site environs should be available while preparing for measurements. The fixed source position and all measurement locations should be annotated on that map.

## 5.3 Meteorological Observations:

5.3.1 Observe and record wind speed, relative humidity, and temperature for potential effects on the sound level meter instruments, and these factors plus wind direction for potential effects on sound propagation from the fixed sound source to each measurement location. General accuracy meteorological instruments should be available to measure:

5.3.1.1 Wind speed (5-km/h or 2.5-mph increments),

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

5.3.1.3 Relative humidity (in 10% increments), and

5.3.1.4 Dry bulb temperature (in 2°C or 5°F increments).

**NOTE 2**—NOAA weather reports may be used for wind, temperature, and humidity data when meteorological instruments are not available on site.

5.3.2 Site absolute atmospheric pressure may be required for the proper use of the microphone calibrator. See Appendix X1.

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

## 6. Calibration and Noise Floor

6.1 The measurement system should be calibrated and its noise floor determined according to Appendix X1.

## 7. Interference from Airborne Sound and Electromagnetic Fields

7.1 Sound level meter measurements are subject to interference from a number of sources, some of which are discussed in Appendix X2.

## 8. Measurement Plan and Procedure

8.1 A measurement plan should be established to produce accurate data according to the stated objectives of the test (see Guide E 1779). These objectives should be coordinated with the sponsoring person or agency, and if possible with representatives of any contending person or agency.

8.2 *Measurement Locations*—Establish a source envelope which just encloses the noise sources. This may be a rectangle  $A \times B$ , or any other appropriate shape around the fixed source or source complex, for example, a pumping station or amphitheatre. Prescribe a measurement surface at 10 m or some other fixed distance from that inner surface and where there is confidence that the measurements so made will be meaningful

in representing the sound level in that azimuthal direction of that or other identical fixed noise sources in the foreseeable future. See Fig. 1. Sound level measurements should be made on this source emission surface for reference in evaluating sound level data obtained at greater distances.

8.2.1 Use USGS 7 + minute topographic maps or appropriate site plans as a graph layout medium. Circumscribe circles outside and centered on the centroid of the source envelope. The radius ranges selected should be divided into nominal logarithmic increments that result in equal decibel level reductions with a minimum of two radii. For example, the set of 30 m, 100 m, 300 m, and 1000 m will produce level reductions of about 10 dB each, but any convenient values may be used. It is emphasized that at distances beyond 30 m and especially beyond 300 m, the sound diminishment with distance will be strongly influenced by wind, temperature gradients, and ground conditions. In addition, the received level is modified by interference between the direct wave and the wave reflected from the ground. The maximum radius where measurements will be significant is determined by a distance where background sounds from other sources dominate over the sound source of interest. Noise measurements may be conducted beyond this range in community areas where noise annoyance has been shown to exist due to the source.

8.2.2 Choose a minimum of four points about the azimuth, for example, north, east, south, and west. These may be adjusted for local conditions such as access, barriers, reflectors, and interference and community concern for noise from the source (see X2.5 and X2.6). Thus, at least eight measurement locations are selected, four on the source measurement surface and four at the maximum radius.

8.2.3 Locations, times, and sound level meter settings (time weighting and frequency weighting filter) for sound level measurements (see X2.4) should be consistent with the reason for making the measurements, as stated in the measurement plan, and the manner in which the data results will be used. Establish limits of wind speed and interference according to the measurement plan (see X1.2, X1.5 and X1.6).

8.2.4 The sound level meter microphone should be mounted on a tripod or pole 1.5 to 2 m above the ground surface, unless otherwise specified in the measurement plan. Higher locations should be chosen where human occupancy is likely, for example, the future top story of a high-rise building.

8.2.5 *Measurement Location Descriptions*—A measurement location description should be prepared as part of this measurement plan. 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 visible or apparent from the measurement sites.

8.3 *Measurement of Pure Tones and Impulsive Sounds*—Since annoyance by sound is a strong function of spectral content, at least one observation of a spectral nature shall be made at each distance.

8.3.1 If pure tones are emitted by the fixed source under test, the frequency of those tones should be measured, or a tape recording of that sound should be made for subsequent analysis.

8.3.2 If impulsive sound is emitted by the fixed source under test, the appropriate sound level meter settings should be specified. See X2.4 and refer to ANSI S1.13.

8.4 *Measurement Location and Time*—For repeatable measurements, sound levels should be measured at short distances according to ANSI 12.18. Alternatively the sound level can be measured over a long time period, which includes various atmospheric conditions, and according to Test Method E 1503 to obtain the maximum expected sound level.

8.4.1 For distances less than 300 m from the source centroid, the sound may be measured any time that the fixed sound source is known to be operating in the conditions set forth in the measurement plan. Variation of the source sound level should be considered. For any source distance, measurements should be made at least over the time period when annoyance by noise from the source can occur. Interference, atmosphere, and ground anomalies noted in 8.2.1 may reduce the measured sound level by 20 dB or more under less than ideal propagation conditions.

8.4.2 The measurement duration should be sufficient to characterize the noise source of interest at each measurement location. Round-the-clock monitoring and acquisition of variable source level statistics should be obtained and calculated according to Test Method E 1503.

8.5 The sound measurement equipment may be prepared according to Annex A1.

8.6 Conduct the measurement.

8.6.1 Measure the sound level from the fixed source according to 8.4. The response rate, filter settings, data sampling time, averaging time, whether impulsive noise is to be measured separately, and the like, shall be determined by the measurement plan, or specified uniquely for this test.

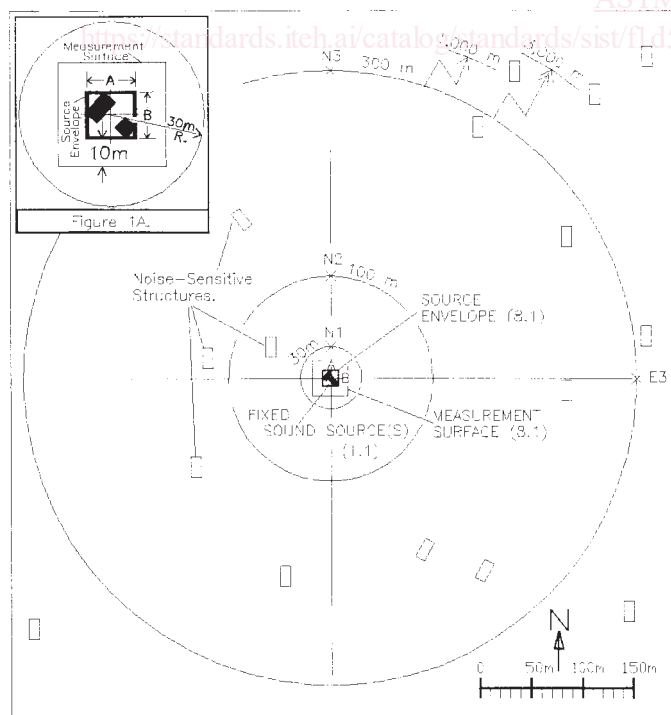


FIG. 1 Arrangement of Measurement Locations About a Fixed Source

8.6.2 Measure the background sound level when the fixed source is not operating. If this is not possible due to continuous source operation, then measure the background sound level in a nearby or cognate location where the environmental noise is believed to be similar to that at the measurement location.

8.6.3 If the background level is more than 10 dB below the fixed source level, then no correction is needed. If the background level is 3 to 10 dB below that of the fixed source, then correct by subtraction the background noise energy from the measurement signal energy. If the background is less than 3 dB below that of the fixed noise source, then it can only be stated that the fixed noise level is less than that measured.

**NOTE 3**—If it is necessary to evaluate the fixed noise source level even when less than 3 dB above the background, it is recommended that a band filter be used to isolate the prominent source noise components from other environmental sounds. Alternatively, the broadband output audio may be recorded over several minutes for subsequent spectral analysis.

8.7 Annex A2 provides guidance for keeping the measurement log.

8.8 Annex A3 provides guidance for preparing the measurement agent.

## 9. Precision and Bias

9.1 The instrument precision of the data obtained using this guide is a function of the acoustical instruments used. See

ANSI S1.4. For steady noise, the precision for the measurement result of the set or subset will be  $\pm 1$  dB for a Type 1 meter and  $\pm 2$  dB for a Type 2 meter.

9.2 This guide has no bias because the sound levels are defined only in terms of this guide.

### 9.3 Variability of Measurement Results:

9.3.1 Atmospheric changes at or near the surface cause significant variations in the propagation of sound to locations 100 m or more from the source. Critical variables are wind direction and vertical gradients of wind speed and of air temperature. The subsequent changes to the sound level will increase with distance. At positions considerably greater than 300 m from the source, the sound level received from the source could change by as much as 20 dB or more from day to night or from upwind versus downwind. Distant sound levels are greater downwind and in the presence of a temperature inversion (warmer air aloft).

## 10. Keywords

10.1 community noise; fixed sound source; outdoor sound; sound measurement; sound survey

## ANNEXES

### (Mandatory Information)

#### A1. PREPARATION OF EQUIPMENT

A1.1 The following procedure has often been found to be helpful for producing reliable data in an expeditious fashion.

A1.1.1 Check the battery. The useful charge should be sufficient to complete the planned measurement.

A1.1.2 Calibrate the sound level meter in accordance with manufacturer's instructions. See 5.3.2, X1.1, and X2.2. The calibration record for all measurements positions should be used to standardize the data during subsequent data reduction and analysis. If manipulation of the calibration control is performed at any time during this measurement program, a record should be maintained of calibration adjustments over the course of the measurement campaign. The record should show the time(s) at which calibration manipulations were performed and the instrument calibration indication before and after each such manipulation.

A1.1.3 Replace the microphone wind screen(s) and other protective devices removed during acoustical calibration.

A1.1.4 Place the microphone according to 8.2.4. Mark this position on the layout plan called for in 8.1 and to the accuracy specified in 5.2.1.

A1.1.5 Select the weighting and filter bandwidths called for in 8.2. If the analyzer has multiple output channels and if the outputs are being recorded electronically, it is recommended that at least one analysis channel be used for A-weighted sound level.

A1.1.6 Set the averaging time and sample rate called for in the measurement plan. Default settings should use "slow" response time. For digital systems capable of post-processing such as Leq, the "fast" response time may be used. If applicable standards or regulations require the use of slow response in collecting data, this requirement should be followed.

A1.1.7 If a vehicle is used to shelter the operator or the test equipment, the microphone should be located as far away from the vehicle as a microphone cable will allow. At a minimum the distance should be at least 2 + times the largest dimension of the shelter vehicle.

A1.1.8 Unless specified differently in the measurement plan, support the microphone on a sturdy tripod or mast. 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 (10 in.)). 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.

A1.1.9 Following the guidance of the measurement plan or the microphone manufacturer's recommendation, orient the microphone properly with respect to the direction from which sound from the fixed source under test is arriving.

## A2. FIELD LOG

A2.1 Maintain a log during the measurement as a written record, preferably on a pre-printed data entry form. See Fig. A2.1. Include information which is not expected to be printed by the measurement system including the following:

A2.1.1 Describe the locations clearly to associate each measurement position with the description in 8.1. If a sampling plan is being followed, use the name or code assigned to the location by the plan. Note the height of any significant objects that may act as a sound barrier or a sound reflector.

A2.1.2 Record the date, start time, and end time of the measurement. If the measurement is not within the time period called for in 8.3, state the reason for the deviation.

A2.1.3 State the operating conditions of the fixed source under test.

A2.2 Identify the manufacturer, model, serial number, and the last traceable laboratory calibration, for the following acoustical instrumentation system components, when used:

A2.2.1 Sound analyzer or sound level meter, and instrument settings used (for example, weighting network, time-average, impulse, octave band, etc.),

A2.2.2 Microphone,

A2.2.3 Outdoor microphone system, and

A2.2.4 Calibrator.

A2.3 *Environmental Conditions*—Record environmental conditions representative of the measurement set. The information recorded should include the following:

A2.3.1 Temperature,

A2.3.2 Relative humidity,

A2.3.3 Site altitude above sea level (if local pressure is needed for microphone calibration),

A2.3.4 Wind speed and speed range if appropriate,

A2.3.5 Wind direction (direction blowing from) in octants (N, ENE, ... WNW, or multiples of 45 degrees 0°, 45°, ... 315°), and

A2.3.6 Ground surface condition, for example, dry, dew, wet, frozen, snow covered (and snow depth).

A2.3.7 If the measurement period is prolonged, wind direction and speed should be reported frequently, that is, at intervals of no more than 15 min. If the wind speed is close to the threshold at which measurements should be suspended, wind speed should be monitored continuously.

A2.4 *Other Major Sound Sources*—Identify major sound sources other than the fixed source under test and record the distance and direction from each source to the measuring location (see 5.2.1).

A2.5 *Comments*—Provide comments, as necessary, including:

A2.5.1 Unusual sound sources which could not be averted and which should be considered in evaluation of the data. Examples in various situations could be aircraft overflights, railroad operations, barking dogs, birds, crickets, locusts, and frogs,

A2.5.2 Unusual weather conditions, especially thunder,

A2.5.3 When applicable under 8.1, 8.2, or 8.3, note changing acoustical propagation conditions, correlation between wind direction and direction of unexpectedly loud or quiet sounds, and subjective estimates of the relative loudness of other sound sources as compared that coming from the fixed sound source under test.