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Standard Specification for Systems to Measure Sound Levels[1]

This standard is issued under the fixed designation E3091; 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.

1. Scope

1.1 This specification is for measurement systems used in making sound pressure level measurements in buildings in accordance with ASTM standards and guides. Systems for making sound pressure level measurements in other environments are not addressed in this specification. A future expansion of this specification may include these environments. The systems addressed include one or more microphones and associated components to process the output of the microphone measurement system conforms to a sound level meter specification it is sufficient to specify the category of precision and accuracy required by the measurement system and that direction is given in the user manual for proper use. Where the system is composed of components, specifications are given for microphone type and orientation, filters and windscreens.

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

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.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C423 Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method

C634 Terminology Relating to Building and Environmental Acoustics

E90 Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements

E492 Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine

E1111 Test Method for Measuring the Interzone Attenuation of Open Office Components

E1130 Test Method for Objective Measurement of Speech Privacy in Open Plan Spaces Using Articulation Index

E2964 Test Method for Measurement of the Normalized Insertion Loss of Doors

2.2 *Other Standards:*[3,4]

ANSI S1.4-2014/Part 1/IEC 61672-1: 2013 Electroacoustics - Sound level meters – Part 1: Specifications

ANSI S1.4-2014/Part 3/IEC 61672-3: 2013 Electroacoustics – Sound level meters – Part 3: Periodic tests

IEC 61094-4: 1995 Electroacoustics - Measurement Microphones – Specifications for working standard microphones

ANSI/ASA S1.11-2014/Part 1/IEC 61260-1: 2014 Electroacoustics - Octave-band and fractional-octave-band filters – Part 1: Specifications

ANSI S1.40-2006 Specifications and Procedures for Sound Calibrators

IEC 60942:2003 Electroacoustics –Sound calibrators

ANSI S1.17/Part 1-2004 Microphone Windscreens – Part 1: Measurements and Specifications of Insertion Loss in Still Air or Slightly Moving Air

NOTE 1—ANSI S1.4-2014/Part 1 and Part 3 are nationally adopted standards mirroring IEC 61672-1: 2013 and IEC 61672-3: 2013. Therefore only the IEC 61672 standards will be referenced in the rest of this standard. ANSI/ASA S1.11-2014/Part 1 is a nationally adopted standard mirroring IEC 61260-1:2014. Therefore only the IEC 61260-1 will be referenced in the rest of this standard.

[1] This specification is under the jurisdiction of ASTM Committee E33 on Building and Environmental Acoustics and is the direct responsibility of Subcommittee E33.05 on Research.

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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.

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

[4] Available from International Electrotechnical Commission (IEC), 3, rue de Varembé, 1st Floor, P.O. Box 131, CH-1211, Geneva 20, Switzerland, http://www.iec.ch.

3. Terminology

3.1 For definitions of terms used in this specification see Terminology C634.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *diffuse field microphone, n*—a microphone which provides its most uniform frequency response for sound equally incident from all angles, IEC 61094-4 Type D.

3.2.2 *free-field microphone, n*—a microphone which provides its most uniform frequency response when oriented with the plane of its diaphragm perpendicular to the direction of the sound, IEC 61094-4 Type F.

NOTE 2—The complete designation of a working standard microphone according to IEC 61094-4 includes "WS" and a number specifying the diameter for a half inch free-field response microphone be "WS2F".

3.2.3 *frequency response (of microphones), n*—the ratio of the electrical output of the measurement system to the sound pressure microphone dependent on the angle of incidence.

3.2.4 *pressure microphone, n*—a microphone which provides its most uniform frequency response when oriented with the plane of its diaphragm parallel to the direction of the sound, IEC 61094-4 Type P.

3.2.5 *windscreen, n*—a device fitted on to a microphone to reduce the spurious sound pressures generated by turbulent air flowing around the microphone cartridge.

4. Significance and Use

4.1 Microphones and associated measurement systems are used in standard test methods to measure sound pressure levels.

4.1.1 Often the measurement system is obtained from the manufacturer as a complete system including subsystems comprising one or more microphones, signal processing circuitry, a signal analysis system and display. All of these subsystems are designed to conform to a normative sound level meter specification. In such a measurement system:

4.1.1.1 The instruction manual shall contain sufficient information for a user to obtain reproducible sound pressure level measurements in various sound fields and,

4.1.1.2 The performance of the system or sub systems is straight forward to test.

4.1.2 There are other measurement systems that use sophisticated multi-channel analyzers, filters and display systems; however these may not be supplied with a specific microphone so they cannot conform to a normative sound level meter specification. Such a system may be more useful for acoustical testing than a simpler instrument that is fully compliant to a normative sound level meter specification.

4.1.2.1 Even systems that are fully compliant with a normative sound level meter performance specification may have non-compliant modes of operation such as reverberation time measurements.

4.1.2.2 For these systems or non-compliant modes of operation, it is necessary to specify both the filter class and the frequency response characteristics of the microphone orientation of the microphone with respect to the sound source.

4.1.2.3 The performance of a non-compliant system may be more complex to verify because:

(1) There may not be a user manual that encompasses the entire system (see Note 3).

(2) Microphones may selected by the user rather than the manufacturer.

(3) It may not be practical to perform normative periodic performance tests on certain features or functions.

NOTE 3—IEC 61672-3 requires the user manual to be available to a calibration laboratory so that it can perform periodic performance testing.

4.2 This specification addresses:

4.2.1 Reverberation time measurements in diffuse fields as in Test Method C423.

4.2.2 Level differences in diffuse sound fields as in Test Methods E90 and E2964.

4.2.3 Level differences in free-field conditions above a reflecting plane as in Test Method E1111.

4.2.4 Absolute levels in diffuse fields as in Test Method E492.

4.2.5 Absolute levels as in Test Method E1130.

4.3 This specification does not address all situations where sound pressure levels are measured. These include outdoor noise measurement, intensity measurement and measurement along surfaces.

5. Measurement Systems

5.1 The measurement system includes all the components necessary to indicate measured sound pressure levels. The components may include microphones, preamplifiers, cables, processing units, filters, computers, display units, and other peripheral devices. There are two categories of measurement systems:

NOTE 4—IEC 61672-1 defines a system for measuring sound pressure levels as a "sound level meters".

5.1.1 A measurement system that conforms a normative sound level meter performance standard shall meet the class 1 specifications of IEC 61672-1 and have its performance verified using a normative standard for periodic testing, that is, IEC 61672-3.

5.1.2 The performance of a measurement system that has not been designed to conform to the specifications of normative standards shall be tested periodically for class 1 performance criteria in 5.1.3 and 5.1.4 if frequency weighting is to be used. Strict compliance with the procedures in IEC 61672-3 may not be possible since the system may not meet all of the specifications in IEC 61672-1. Periodic testing of performance to a subset of IEC 61672-3 is permissible providing all criteria listed in 5.1.3 are included and if frequency weighting is to be used then the criteria in 5.1.4 are also included.

5.1.3 Performance criteria required for measurement of sound pressure levels in building acoustics are:

5.1.3.1 Indication at the calibration frequency according to IEC 61672-3, Section 10.

5.1.3.2 Self-generated noise according to IEC 61672-3, Section 11.

5.1.3.3 Electrical signal tests of frequency weightings according to IEC 61672-3, Section 13.

5.1.3.4 Frequency and time weightings at 1kHz according to IEC 61672-3, Section 14.

5.1.3.5 Level linearity on reference level range according to IEC 61672-3, Section 16.

5.1.3.6 Level linearity including the level range control according to IEC 61672-3, Section 17.

5.1.3.7 Overload indication according to IEC 61672-3, Section 20.

5.1.4 Acoustical signal tests of frequency weighting according to IEC 61672-3, Section 12.

5.2 Sound level meters designed to meet legacy performance standards may be used if it can be demonstrated that for the frequency bands of interest, for the functions utilized and for the environmental conditions encountered, the sound level meter meets the class 1 specifications of IEC 61672 for the criteria listed in 5.1.3 and, if frequency weighting is to be used, 5.1.4.

6. Requirements for measurement systems designed to conform to IEC 61672-1

6.1 Verify each channel in the measurement system meets the class 1 specifications of IEC 61672-1. Performance testing may be the class 1 periodic tests of IEC 61672-3 or an equivalent periodic testing protocol. Testing shall include the performance criteria listed in 5.1.3, if frequency weighting is to be used 5.1.4 and any additional performance criteria needed to verify the performance of the system for the type of measurements to be performed. Testing with accessories such as windscreens is not required if the measurement system with the accessory installed conforms to IEC 61672-1.

6.2 If the system is to be used for conducting measurements of band-limited sound pressure levels, the system shall include a filter set that conforms to the class 1 specifications of IEC 61260.

6.3 Measurements shall be conducted in compliance with the user manual for microphone orientation and the use of accessories.

7. Requirements for measurement systems not designed to conform to IEC 61672-1

7.1 The requirements for a measurements system which is not designed to conform to a normative sound level meter performance standard may be satisfied by verifying that each measurement channel meets the class 1 criteria in IEC 61672-1 for the performance criteria in 5.1.3 and if frequency weighting is to be used 5.1.4, using IEC 61672-3 or an equivalent periodic testing protocol where the responses of individual components are combined to determine the performance of each channel of the overall system.

7.2 If the measurement system is to be used for performing measurements of band-limited sound pressure levels, the system shall include a filter set that conforms to the class 1 specifications of IEC 61260-1.

7.3 If windscreens are employed and either absolute values of sound pressure level are being measured, or the windscreens are not identical, the insertion loss of the windscreen(s) must be compensated for using information supplied by the manufacturer of the windscreen (see ANSI S1.17/Part 1).

7.4 *For measurement of reverberation times*—Microphones may be type D (Diffuse field), type P (Pressure), or type F (Free-field).

7.5 *For measurement of differences between sound pressure levels in spaces designed to be diffuse:*

7.5.1 All microphones must satisfy the requirements of IEC 61094-4 for type D (Diffuse field) or the requirements for type P (Pressure) or if free-field microphones are used, a correction must be applied to achieve a similar response. If combinations of type D and type P are used, corrections supplied by the manufacturer shall be applied to achieve a similar frequency response (see Appendix X1).

7.5.2 If multiple microphones or measurement channels, or both, are used, each measurement channel shall be excited with a sound level calibrator and adjusted to indicate the level specified by the calibrator for the microphone type (see Note 5).

7.6 *For measurement of differences between sound pressure levels in spaces designed to be free-field or free-field above a reflecting plane:*

7.6.1 All microphones shall satisfy the requirements of IEC 61094-4 for type F (Free-field) microphones or corrections supplied by the manufacturer shall be applied to results from other types of microphones to achieve a similar frequency response.

7.6.2 Microphones shall be oriented with their principal axes towards the sound source.

7.6.3 If multiple microphones or measurement channels, or both, are used, each measurement channel shall be excited with a sound level calibrator and adjusted to indicate the level specified by the calibrator for the microphone type (see Note 5).

7.7 *For measurement of absolute sound pressure levels in spaces designed to be diffuse:*

7.7.1 All microphones must satisfy the requirements of IEC 61094-4 for type D (Diffuse field) or the requirements for type P (Pressure) or free field with corrections. Each measurement channel, taking into account the documented frequency response of the associated microphone shall meet class 1 of IEC 61672-1 or an equivalent specification.

7.7.2 Each measurement channel shall be excited with a sound level calibrator and adjusted to indicate the level specified by the calibrator for the microphone type (see Note 5).

7.8 *For measurement of absolute sound pressure levels in spaces designed to be free-field or free-field above a plane:*

7.8.1 Microphones shall satisfy the requirements of IEC 61094-4 for Type F (Free-field)or corrections supplied by the manufacturer shall be applied to results from other types of microphones to achieve the same frequency response.

7.8.2 Microphones shall be oriented with their principal axes toward the sound source.

7.8.3 Each measurement channel shall be excited with a sound level calibrator and adjusted to indicate the level specified by the calibrator for the microphone type (see Note 5).

NOTE 5—If multiple microphones are used, it is recommended that all:

(1) Have the same diameter. *(2)* Have same response type (free-field, pressure or diffuse field). *(3)* Have a documented measured frequency response (this is not needed for measurements of reverberation time). *(4)* Utilize the same type of windscreen if employed.

NOTE 6—When adjusting the gain of measurement channels, the indicated sound pressure level should reflect any bias in the output of the acoustical calibrator as determined by periodic calibration and any correction factors described in the user manual of the acoustical calibrator for the type of microphone connected to the input of the measurement channel.

8. Keywords

8.1 diffuse field; free-field; measurement system; microphone; pressure; sound level meter

APPENDIX

(Nonmandatory Information)

X1. PRACTICAL CONSIDERATIONS REGARDING MICROPHONE RESPONSE

X1.1 Microphones are designed to have relatively uniform sensitivity in one of three types of sound fields, free field, diffuse field and pressure field (types F, D, P) over a wide range of frequencies. To achieve relative uniformity in different sound fields, they are designed to respond differently to sound as a function of angle of incidence. Differences in frequency response between types of ½ in. microphones are small up to 4000 Hz. Above 5000 Hz, significant differences may occur between microphones of different types and above 10 000 Hz variations may occur among microphones of the same type. At high frequencies, all microphones will respond with lower output to sound arriving from the side or the rear.

X1.2 Free-Field Response of Microphones

X1.2.1 All microphones will have a lower output signal when oriented off axis from a high frequency source in a free-field.

X1.2.2 The variation in response at high frequencies will be small for a type F microphone when oriented toward the source in a free-field.

X1.2.3 A type D or type P microphone will have a relatively greater output signal at high frequencies when oriented towards the source in a free field. The most accurate readings are when the source is oriented to the side at some angle.

X1.3 Diffuse-Field Response of Microphones

X1.3.1 In a diffuse field, a free-field microphone has a relatively lower output signal at high frequencies since most of the angles of incidence are off-axis where the response is lower.

X1.3.2 A type D, diffuse-field microphone at high frequencies will have an output signal relatively independent of orientation in a diffuse field because it is averaging out the higher response to sound in front with lower response to sound in the rear.

X1.4 Diffuse Versus Pressure Microphones

X1.4.1 A pressure microphone indicates the true sound pressure in a closed cavity or on a surface.

X1.4.2 The frequency response of pressure microphones and diffuse-field microphones are usually similar.

X1.4.3 Most pressure microphones are close to or qualify as diffuse field microphones but some may not.

X1.5 Calibration of Microphones

X1.5.1 There are large differences between microphone types in their response to calibration in a pressure chamber.

X1.5.2 When free-field microphones are calibrated with pressure chambers or electrostatic calibrators, their high frequency response appears to drop off drastically with increasing frequency.

X1.5.3 Adjustments must be made to those calibrations to get the actual response when exposed to sound in open air at various angles.

X1.5.4 The calibration laboratories typically show the 0° response on the calibration curve as well as the actuator response. This cannot be compared to the actuator response of a pressure microphone that will be relatively flat to a high frequency.

X1.5.5 There is a standardized way to show a “random incidence” adjustment of the actuator response of a free-field microphone, but not all laboratories provide it.

X1.5.6 The adjustments for 0° incidence shown on the calibration curve must not be confused with the error of a free-field microphone when used in a diffuse field.

X1.6 Using Combinations of Microphone Types

X1.6.1 When high frequencies are a concern, it is inadvisable to mix microphone types in a system and try to adjust based on calibration frequency response alone.

X1.6.2 At lower frequencies there is less concern.

X1.6.3 While free-field microphones could probably be used safely for comparative measurements and reverberation measurements, it is probably not a good idea to mix free-field and diffuse field microphones in the same set of measurements.