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Standard Guide for Specifying Acoustical Performance of Sound-Isolating Enclosures[1]

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1. Scope

1.1 The guide covers the development of criteria for the acoustical performance of a broad variety of acoustical enclosures by identifying information necessary to unambiguously describe acoustical performance. This guide is not a standard ASTM specification for a sound-isolating enclosure.

1.2 Excluded from the scope of this guide are technical considerations for enclosure design that do not pertain directly to acoustical performance.

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 423 Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method[2]

C 634 Terminology Relating to Environmental Acoustics[2]

E 336 Test Method for Measurement of Airborne Sound Insulation in Buildings[2]

E 413 Classification for Rating Sound Insulation[2]

E 596 Test Method for Laboratory Measurement of the Noise Reduction of Sound-Isolating Enclosures[2]

2.2 *ANSI Standards:*

ANSI S1.4 Specification for Sound Level Meters[3]

ANSI S3.1 Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms[3]

ANSI S3.6 Specification for Audiometers[3]

ANSI S12.31–S12.35 Methods for Determining the Sound Power Levels of Machines and Equipment[3]

2.3 *ISO Standard:*

ISO 3741–3745 Acoustics—Methods for Determining the Sound Power Levels of Machines and Equipment[3]

2.4 *Government Standard:*

29 CFR 1910.95 Occupational Noise Exposure [Occupational Safety and Health Administration][4]

2.5 *Other Standard:*

VDI 2711 Schallschutz durch Kapeslung [Verein Deutscher Ingeireure, Beuth Verlag GmbH, Berlin] [German] [Noise Control by the Use of Enclosures][5]

3. Terminology

3.1 *Definitions:*

3.1.1 Standard definitions of acoustical terms may be found in Terminology C 634.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *A-weighted sound pressure level*—sound pressure level measurements made with the A-weighting filter applied as defined in ANSI S1.4, denoted L_{PA} in this guide.

3.2.2 *C-weighted sound pressure level*—sound pressure level measurements made with the C-weighting filter applied as defined in ANSI S1.4, denoted L_{PC} in this guide.

3.2.3 *enclosure*—a structure, usually free-standing, which substantially or completely encloses a given space or object. This does not include barrier walls, partitions within a building, or other partial structures.

3.2.4 *enclosure-generated noise*—sound created by the operation of the enclosure systems, such as lighting and ventilation.

3.2.5 *level reduction*—for the purposes of this guide, the arithmetic difference between sound pressure levels at a specific location before and after the installation of the enclosure, expressed in decibels.

3.2.6 *level reduction specification*—specification of the acoustical performance of an enclosure by stating the reduction in sound pressure level caused by the enclosure.

3.2.7 *personnel enclosure*—an enclosure designed to keep sound energy from personnel or equipment therein. Examples of personnel enclosures include but are not limited to audiometric booths, in-plant offices, broadcast booths, and acoustical test chambers.

3.2.8 *pre-installation sound pressure levels*—the sound pressure levels, as a function of frequency, that are present prior to the installation of the enclosure. In most cases this is determined by measuring the ambient sound pressure levels in

[1] This guide is under the jurisdiction of ASTM Committee E-33 on Environmental Acoustics and is the direct responsibility of Subcommittee E33.03 on Sound Transmission.

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

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

[4] Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

[5] Available from Beuth Verlag GmbH, Burggrafenstrasse 4-7, 1000 Berlin 30.

the host area but in some cases, such as new construction, the sound pressure levels must be predicted.

3.2.9 *sound pressure level specification*—specification of the acoustical performance of an enclosure by stating the maximum sound pressure levels that shall exist after installation.

3.2.10 *source enclosure*—an enclosure designed to keep sound energy from personnel or equipment on the outside. Such applications include, but are not limited to, equipment silencing, secure communications, music practice, and acoustical testing.

4. Summary of Guide

4.1 An explanation of the determination and subsequent specification of acoustical performance of sound-isolating enclosures is presented.

4.2 Two types of specifications are described in this guide. The recommended method (sound pressure level specification) is to specify the maximum permissible sound pressure levels that may be present after installation of the enclosure. The alternate method (level reduction specification) is to specify the enclosure's level reduction.

4.3 The type of specification selected depends largely on the enclosure application and the data available. A sound pressure level specification usually applies to a specific site, while the level reduction specification may have broader application. Also, the sound pressure level specification is more appropriate where specific sound pressure levels are required, while the level reduction specification reflects a more general interest in amounts of noise level reduction.

4.4 Some guidance is provided in Appendix X1 on selecting a specification type based on the enclosure application and the information available.

4.5 Substantial guidance is given on the essential acoustical data that must be compiled.

4.6 A non-mandatory model specification Appendix X2 is included that embraces both specification types. It also serves as a guide for identifying and gathering information necessary to the manufacturer for designing the enclosure.

5. Significance and Use

5.1 This guide can be used to produce a specification for the acoustical performance of an enclosure.

5.2 This guide is intended for those familiar with basic concepts of acoustics.

5.3 Although this guide provides detailed guidance in matters relating to specification of acoustical enclosures, it is not a substitute for the experience and judgment of an acoustical or noise control professional.

5.3.1 This guide calls for measurements common within acoustical practice.

5.3.2 The more critical the performance requirements of the enclosure, the more the user should consider seeking the services of an acoustics or noise control professional.

5.4 The specifying of a sound-isolating enclosure has three sequential steps:

5.4.1 Determine the sound pressure levels that exist at specific locations prior to the introduction of the enclosure,

NOTE 1—In the case of new construction, the sound pressure level is often estimated from the sound power levels of noise-emitting equipment and a general description of the acoustical properties of the environment.

5.4.2 Determine the maximum permissible sound pressure levels that must exist at the same locations after the introduction of the enclosure, and

5.4.3 Determine the required enclosure level reduction. The required isolation is related to the difference between the sound pressure levels before and after the introduction of the enclosure.

5.5 Many specifications are for multiple enclosures or enclosures with multiple functions, or both. It is beyond the scope of this guide to provide detailed guidance for every possible combination. Separate specifications for each source-enclosure-receiver combination should be used in such a case.

5.6 The type of specification that should be selected depends both on the purpose of the enclosure and how crucial its performance is. In general:

5.6.1 If exceeding a particular maximum permissible sound pressure level spectrum would render the enclosure unsuccessful, a sound pressure level specification should be used.

5.6.1.1 This guide assigns all phases of acoustical design are delegated to the supplier. Compliance is usually more easily verified than with the level reduction method.

5.6.2 If the criteria for the success of the enclosure are less stringent or not related to a specific maximum permissible spectrum, a level reduction specification may be used.

6. Recommended Specifications

6.1 The sound pressure level specification specifies the maximum permissible sound pressure levels that may exist either inside or outside the enclosure after installation. Pre-installation sound pressure levels must also be presented.

6.1.1 Maximum sound pressure levels should be specified in one-third-octave bands whenever possible to allow a detailed fit to the requirements. Octave band sound pressure levels are appropriate where the noise spectrum is broad band and free of prominent tones.

6.1.2 The desired post-installation sound pressure level may also be described by a single number descriptor, such as A-weighted sound pressure level or NC or RC ratings.[6] In this event the pre-installation one-third-octave band sound pressure levels at or around the installation site shall also be provided.

NOTE 2—Other single number ratings for noise may also be available. For further information see ASHRAE Handbook.[6]

6.1.3 Measured sound pressure levels are preferred. When not available, such as in the case of new construction, the following information is usually considered an acceptable substitute to allow estimation of sound pressure levels:

6.1.3.1 The rated or measured sound power level (here denoted L_W) of equipment and,

6.1.3.2 A description of the host environment, including the relative locations of sources of noise, personnel, and the enclosure. Some loss of accuracy should be expected.

6.1.4 Inaccurate measurement of sound pressure levels can result from unsteady or intermittent sources of noise during

[6] *ASHRAE Handbook, Fundamentals*, Chapter 7, American Society of Heating, Refrigerating and Air Conditioning Engineers, Atlanta, Georgia.

measurement, changes in site conditions after measurement (for example, significant sources of noise arising between measurement and installation), strong low frequency content ($L_{PC} - L_{PA} > 15$), and general inexperience with acoustical measurements.

6.1.5 Maximum permissible sound pressure levels are often prescribed for particular applications by standards or regulatory documents. A short list includes, but is not limited to, hearing conservation regulations, architectural specifications, human comfort, speech intelligibility, speech privacy, and acoustical test standards. Common specific cases are cited in Appendix X1.

6.1.6 The maximum permissible interior or exterior sound pressure levels should not be exceeded with all sources of enclosure-generated noise in normal operation.

6.2 The level reduction specification identifies the minimum permissible level reduction to be provided by the enclosure. This type specification is often used by a buyer who has already determined the isolation needed to meet his sound pressure level requirements. Using this type of specification without such analysis could result in unacceptable results.

6.2.1 Level reduction *I(f)* can be approximated as follows:

$$I(f) = L_1 - L_2 + SF$$

where:

L_1 = pre-installation sound pressure level in a given band,
L_2 = post-installation sound pressure level in a given band, and
SF = safety factor.

6.2.1.1 The safety factor helps ensure compliance by accounting for unforeseen complications due to changes in site conditions, or unusual acoustical interactions of the enclosure and the space. The more critical the successful performance of the enclosure, the larger the selected safety factor should be. Typical values are:

Not Critical....	SF = 0 dB
Moderate....	SF = 3 dB
Conservative....	SF = 6 dB

NOTE 3—In practice safety factor size varies with frequency as well as with importance. The user should consider applying stringent safety factors only in bands where they are most needed in order to avoid over-designing the enclosure.

6.2.1.2 The introduction of the enclosure may significantly alter the sound field near the noise source, increasing both the effective value of L_1 and the required level reduction. This effect is important when either the physical volume or the sound absorption coefficients of the surfaces around the noise source are reduced by a factor of two or more. In this case, detailed information on noise source and its pre-installation surroundings should accompany the specification. In addition, a larger safety factor should be considered.

6.2.2 The level reduction of enclosures is typically quantified by the manufacturer in laboratory prototype testing. Noise reduction (NR) is measured per Test Method E 596, and noise isolation class (NIC) is calculated per Classification E 413. For the purposes of this guide, noise reduction data are an acceptable equivalent for level reduction.

6.2.2.1 Custom designs are typically not tested, due to cost.

6.2.2.2 The actual enclosure being specified may differ in certain particulars from prototypes tested.

6.2.2.3 Because of variations in manufacturing materials and methods and changes in test standards, test results should be no older than five years.

6.2.2.4 Laboratory noise reduction data obtained in accordance with Test Method E 596 in prototype testing are often accepted as performance verification.

6.2.3 An enclosure may provide the required level reduction without achieving a particular sound pressure level spectrum in the protected space. As an example, sound pressure levels inside an enclosure will be considerably higher when the enclosure is located in a high ambient noise area.

7. Other Noise Control Properties of Enclosures

7.1 *Vibration Isolation*—The effectiveness of an enclosure can be compromised by structure-borne noise bypassing the acoustical barrier through adjacent building structures. Enclosures should be isolated from adjacent structures by means of flexible connections.

7.1.1 Vibrations that can be felt by the hand are an indication that measurements of vibration levels are necessary.

NOTE 4—In typical installations, structure-borne vibration treatments are part of the enclosure. Special cases, for example, broadcast studios, generally require measurement or analysis of structure-borne vibration patterns of the host environment prior to specification, or both, where applicable.

NOTE 5—The L_a measurement and treatment of structure-borne vibration are difficult. Measurements are complicated and an ineffective treatment can actually be counterproductive. In critical situations an expert should be consulted.

7.2 *Interior Sound Absorption*—Most applications benefit from sound absorption within the enclosure. Insufficient sound absorption has two effects: a more reverberant sound field can affect speech intelligibility and the ability to localize sound generated within the enclosure. Low sound absorption can reduce sound isolation performance.

7.2.1 Sound absorption is properly expressed in terms of the sound absorption coefficient of the absorbing surfaces determined in a laboratory in accordance with Test Method C 423.

7.2.2 One may alternatively specify the noise reduction coefficient (NRC) that is a single-number rating for the average sound absorption coefficients in the speech frequency bands.

7.2.3 Another method for specifying the internal absorption of an enclosure is the reverberation time T_{60}, which is defined as the time it takes for a reverberant sound field to decay 60 dB after the source is interrupted.

NOTE 6—All highly absorbent enclosures suppress the reverberant sound field. Enclosure volumes may be too small for meaningful measurements of T_{60}, and physical and equipment limitations may preclude the valid measurement of reverberation time entirely. Until a standard is promulgated for accurately making such a measurement, performance verification established by measurement of T_{60} should be used with caution.

8. Performance Verification

8.1 If performance verification is required, it should be stated explicitly in the specification.

8.1.1 For a sound pressure level specification, performance verification is accomplished by comparing the specified sound pressure levels with the measured sound pressure levels at the

designated location after enclosure installation. Compliance is demonstrated when sound levels measured at the location in question are less than the maximum permissible sound pressure levels specified. Sound pressure levels at the site should also be checked to make sure that conditions have not changed.

8.1.2 Verification of a level reduction specification is somewhat more complicated. Measurements of field noise reduction are typically made according to Test Method E 336; compliance is demonstrated when field noise reduction figures attain or exceed level reduction values specified. However, this guide does not cover all possible test configurations, especially those where one of the spaces is small. Efforts are underway within ASTM to produce a test standard that addresses such cases.

8.1.2.1 Level reduction may not be numerically equivalent to the noise reduction as defined in Terminology C 634 and used in Test Methods E 596 and E 336 because of alterations to pre-installation sound pressure levels brought about by the introduction of the enclosure.

8.1.2.2 Field noise reduction data obtained according to Test Method E 336 tracks noise reduction data measured using Test Method E 596 in the laboratory with some allowance for variations and imperfections in field conditions. A tolerance of ±3 to 6 dB is reasonable when comparing data obtained with the two methods.

9. Keywords

9.1 buildings; enclosures; insertion loss; level reduction; noise reduction; rooms; specifications

APPENDIXES

(Nonmandatory Information)

X1. TYPICAL ENCLOSURE APPLICATIONS AND THEIR SPECIFICATION

X1.1 *Audiometric Enclosures*—Two standards govern the specification of audiometric test enclosures: ANSI S3.1 and ANSI S3.6. ANSI S3.1 gives the maximum permissible ambient sound pressure levels for the cases of "ears open" and "ears covered" audiometric testing. Thus a sound pressure level specification is most appropriate. ANSI S3.6 governs the sound absorption coefficients of the interior surfaces of the enclosure.

X1.1.1 These enclosures are often specified in terms of level reduction because they are used almost exclusively in office environments for which existing ambient levels are easily measured or estimated.

X1.2 *Industrial Enclosures*—OSHA Regulations (29 CFR 1910.95) govern industrial hearing conservation programs. There may be other state and local requirements as well. The goal is typically to provide an A-weighted level less than 85 dB so that hearing conservation measures are not required. Either the sound pressure level or level reduction type of specification is appropriate, provided that the maximum permissible A-weighted sound pressure level and pre-installation sound pressure level spectrum are given.

X1.3 *Broadcast Enclosures, Modular Studios*—These are often specified in terms of the NC-rating permissible inside the enclosure during recording or broadcast. A sound pressure level specification is appropriate.

X1.3.1 Typical NC values for studios are NC-10 to NC-25. With the advent of digital recording the trend is towards quieter studios.

X1.3.2 The user should be aware that noise generated by recording and amplification equipment can be significant and, unless addressed specifically, is not considered in either the host space ambient noise or the enclosure-generated noise.

X1.4 *Music Practice Rooms*—Isolate two dissimilar noisy spaces from each other. There is little agreement on how much intrusive noise a musician can hear and still effectively practice or perform his/her part. These rooms typically are specified by noise isolation class (NIC).

X1.4.1 The number of players and their instrument type expected in each room should be specified. One should also describe the characteristics (size, acoustical treatments, use) of the space adjacent to the music practice room.

X1.5 *Secure Communications Facilities*—These enclosures serve to isolate conversations and generally prevent spoken information from being detected outside the enclosure. Since conversational sound pressure levels are well known, these enclosures are often specified in terms of noise reduction per Test Method E 596.

X2. MODEL SPECIFICATION

NOTE X2.1—This model specification is based loosely on one found in VDI 2711.

X2.1 The following is suggested as a model upon which to build a specification more appropriate to a particular application.

X2.1.1 These requirements are a:

☐ Sound pressure level
☐ Level reduction specification for an acoustical enclosure

The intended application is:

☐ Noise Inside Enclosure, Protected Area Outside
  ☐ Industrial equipment enclosure
  ☐ Secure communications enclosure
  ☐ Music practice room
  ☐ Other _____

☐ Noise Outside Enclosure, Protected Area Inside
  ☐ Audiometric booth
  ☐ Broadcast or recording studio
  ☐ Music practice room
  ☐ In-plant office
  ☐ Conference room
  ☐ Other _____

X2.2 *Dimensions of Enclosure (Attach Sketch Where Possible):*

X2.2.1 *Exterior Maximums*:

☐ Height _____
☐ Width _____
☐ Length _____

X2.2.2 *Interior Minimums:*

☐ Height _____
☐ Width _____
☐ Length _____

X2.2.3 *Entrance and Access Requirements*:

_____

X2.3 *Host Environment:*

X2.3.1 *Description of Host Environment (Include Sketch Where Possible)*:

☐ Dimensions _____
☐ Construction _____
☐ Sound absorbing surfaces
  ☐ Type _____
  ☐ Location _____
  ☐ Area covered _____

X2.3.2 Attach a sketch showing relative locations of:

☐ Significant noise sources,
☐ Enclosure(s), and
☐ Personnel

X2.3.3 Noise- or vibration-producing activities taking place in host space:

_____

X2.3.4 Noise- or vibration-producing activities taking place in adjacent spaces:

_____

X2.3.5 Activities to be isolated from the above:

_____

X2.4 *Minimum Level Reduction Values in dB for Enclosure:*

NOTE X2.2—The information in X2.4 is required for a level reduction specification and should be omitted for a sound pressure level specification.

☐ In ⅓-octave bands:
☐ In octave bands:

Freq. [Hz]	63	125	250	500	1000	2000	4000	8000	A-wght
I									

X2.4.1 Isolation measurement locations (include sketch where possible), before and after installation of enclosure:

☐ Not known
☐ Not applicable to this specification

X2.5 *Noise Source Information:*

NOTE X2.3—The information in X2.5 is required for a sound pressure level specification and is optional, although helpful, for a level reduction specification.

X2.5.1 Pre-installation sound pressure levels (dB) due to sources to be isolated: Lp_{ON}

☐ ⅓-octave ☐ Octave band values are ☐ already A-weighted ☐ unweighted

Freq. [Hz]	63	125	250	500	1000	2000	4000	8000	L_{PA}
Lp_{ON}									

X2.5.2 Pre-installation sound pressure levels (dB) with sources to be isolated not operating, Lp_{OFF}, at same location as X2.5.1:

☐ ⅓-octave ☐ Octave band values are ☐ already A-weighted ☐ unweighted

Freq. [Hz]	63	125	250	500	1000	2000	4000	8000	L_{PA}
Lp_{OFF}									

NOTE X2.4—Lp_{OFF} is the lowest level achievable with internal equipment completely isolated. If this is larger than the desired sound pressure levels, there are other noise sources that must also be controlled.

X2.5.3 Sound power level (L_w in dB) of enclosed equipment in frequency bands per ANSI S12.31-5 or ISO 3741-5:

☐ ⅓-octave ☐ Octave band values are ☐ already A-weighted ☐ unweighted

Freq. [Hz]	63	125	250	500	1000	2000	4000	8000	L_{PA}
L_W									

X2.6 Maximum permissible post-installation sound pressure levels Lp_{MAX} in dB after installation of enclosure (assumes location same as X2.5.1). Specific cases are given below.

NOTE X2.5—Information in this section is necessary for a sound pressure level specification and should be omitted from a level reduction specification.

X2.6.1 *Audiometric*:

☐ per ANSI S3.1 ears open
☐ per ANSI S3.1 ears covered
☐ other octave or ⅓-octave band levels

X2.6.2 *Music Practice:*

☐ Number of musicians inside enclosure _____
☐ Number of musicians outside enclosure _____

X2.6.3 *Broadcast Recording:*

☐ NC Level
☐ Other octave or ⅓-octave band levels

X2.6.4 *Other:*

_____

Freq. [Hz]	63	125	250	500	1000	2000	4000	8000	NIC	L_{PA}
Lp_{MAX}										

NOTE X2.6—Sound levels due to the operation of enclosure subsystems such as electrical and ventilation shall be included in the above levels.

X2.7 *Internal Acoustical Treatment:*

X2.7.1 *Materials*:

☐ Glass fiber
☐ Mineral fiber
☐ Other _____
☐ Manufacturer's discretion

X2.7.2 *Covered With:*

☐ Perforated metal
☐ Polyester film
☐ Fabric
☐ Other _____
☐ Manufacturer's discretion

X2.7.3 Sound absorption coefficients α of sound absorbing surfaces (if known), in octave bands or noise reduction coefficient (NRC), or both.

Freq. [Hz]	63	125	250	500	1000	2000	4000	8000	NRC
α									

X2.7.4 *Areas to Be Covered by Absorbing Panels Relative to Reflecting Panels:*

☐ Specific locations (sketch)
☐ Percentage of surface area
☐ Manufacturer's discretion

X2.7.5 *Reverberation Time in Seconds:*

NOTE X2.7—This information appropriate only in situations for which verification is possible. See 7.2.

Freq. [Hz]	63	125	250	500	1000	2000	4000	8000
T_{60}								

X2.8 *Vibration Isolation:*

X2.8.1 The following information is provided:

☐ Pre-installation ☐ ⅓-octave ☐ octave band floor acceleration levels (La_{ON}, dB re 10^{-5} m/s^2) with equipment to be isolated in operation.
☐ Pre-installation ☐ ⅓-octave ☐ octave band floor acceleration levels (La_{OFF}, dB re 10^{-5} m/s^2) with equipment to be isolated not operating.
☐ General instructions: ☐ Provide vibration isolation
☐ Vibration isolation at manufacturer's discretion
☐ Do not provide vibration isolation

Freq. [Hz]	63	125	250	500	1000	2000	4000	8000
La_{ON}								
La_{OFF}								

X2.9 *Field Performance Verification:*

The performance of the enclosure
☐ will not
☐ will
be measured after installation. The performance verification will consist of
☐ Measurement of post-installation sound pressure levels—
☐ Internal
☐ External
☐ N/A
☐ Enclosure sound isolation per (standard)
_____
☐ Other _____