Acoustical Society of America

ANSI/ASA S12.60-2010/Part 1 American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 1: Permanent Schools

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ANSI/ASA S12.60-2010/Part 1
(Revision of ANSI/ASA S12.60-2002)

AMERICAN NATIONAL STANDARD

Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 1: Permanent Schools

ANSI/ASA S12.60-2010/Part 1

Accredited Standards Committee S12, Noise

Standards Secretariat
Acoustical Society of America
35 Pinelawn Road, Suite 114 E
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ANSI/ASA S12.60-2010/Part 1
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AMERICAN NATIONAL STANDARD

Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 1: Permanent Schools

Secretariat:

Acoustical Society of America

Approved April 28, 2010 by:

American National Standards Institute, Inc.

Abstract

This document is Part 1 of the ANSI/ASA S12.60 series and is applicable to classrooms and other learning spaces in permanent schools. Part 2 of the ANSI/ASA S12.60 series is applicable to relocatable classrooms and relocatable modular core learning spaces. This standard includes acoustical performance criteria, and design requirements for classrooms and other learning spaces. Annex A provides procedures for optional testing to determine conformance with the source background noise requirements and the noise isolation requirements of this standard. Annex B provides commentary information on various paragraphs of this standard. Annex C provides guidelines for controlling reverberation in classrooms.

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Foreword

[*This Foreword is for information only and is not a part of the American National Standard ANSI/ASA S12.60-2010/Part 1 American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 1: Permanent Schools.*]

This standard comprises a part of a group of definitions, standards, and specifications for use in noise. It was developed and approved by Accredited Standards Committee S12, Noise, under its approved operating procedures. Those procedures have been accredited by the American National Standards Institute (ANSI). The Scope of Accredited Standards Committee S12 is as follows:

> *Standards, specifications, and terminology in the field of acoustical noise pertaining to methods of measurement, evaluation, and control, including biological safety, tolerance, and comfort, and physical acoustics as related to environmental and occupational noise.*

At the time of publication of this document, the ANSI/ASA S12.60 series of standards includes the following American National Standards:

- ANSI/ASA S12.60-2010/Part 1 *American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 1: Permanent Schools*
- ANSI/ASA S12.60-2009/Part 2 *American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 2: Relocatable Classroom Factors.*

Work is also underway on a new part, ANSI/ASA S12.60/Part 3, *American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 3: Information Technology Equipment in Classrooms.* An informative technical report is also planned as Part 4 of this series which is envisioned to cover, at a minimum, the topics previously included in ANSI/ASA S12.60-2002 (R 2009), Annexes A, B, D, F and G.

This standard is not comparable to any existing ISO Standard.

At the time this standard was submitted to Accredited Standards Committee S12, Noise, for approval, the membership was as follows:

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Suggestions for improvements to this standard will be welcomed. They should be sent to Accredited Standards Committee S12, Noise, in care of the Standards Secretariat of the Acoustical Society of America, 35 Pinelawn Road, Suite 114E, Melville, New York 11747-3177. Telephone: 631-390-0215; FAX: 631-390-0217; E-mail: asastds@aip.org.

Introduction

It is essential that both architectural and mechanical design provide good acoustical characteristics for classrooms and other learning spaces in which speech communication is an important part of the learning process. Excessive background noise or reverberation in such spaces interferes with speech communication and thus presents an acoustical impediment to learning. With a classroom having good acoustical characteristics, learning is easier, deeper, more sustained, and less fatiguing. Teaching should be more effective and less stressful with well designed acoustical characteristics in a classroom. There can be more verbal interaction and less repetition between teacher and students when spoken words are clearly heard and understood. All those in a classroom, including teachers and adult learners, will benefit from a classroom having the acoustical characteristics recommended in this standard. Special beneficiaries are young children and persons with hearing, language, speech, attention deficit, or learning disabilities. Conformance to the requirements and guidelines of this standard will improve the quality of education by eliminating acoustical impediments for all students and teachers, including those with communication disabilities. This standard seeks to provide flexibility for the design of learning spaces without compromising the goal of obtaining adequate speech intelligibility for all students and teachers in classrooms and learning spaces within the scope of this standard.

American National Standard

Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 1: Permanent Schools

1 Scope and purpose

1.1 Scope

1.1.1 Part 1 of ANSI/ASA S12.60 is applicable to core learning spaces and classrooms with interior volumes not exceeding 566 m^3 (20 000 ft^3) and to ancillary learning spaces of any volume. Learning spaces with volumes larger than 566 m^3 (20 000 ft^3) are considered ancillary learning spaces for purposes of this standard. Annex A provides testing procedures when optional tests are performed to determine conformance with the source background noise requirements and the noise isolation requirements of this standard. Annex B provides commentary information on various paragraphs of this standard. Annex C provides guidelines for controlling reverberation in classrooms and other learning spaces.

This Part does not apply for natatoria, auditoria, music performance spaces, teleconferencing rooms, or special education rooms such as those for severely acoustically challenged students, which all require special acoustical design and treatment that is not within the scope of this standard. This Part does not apply to relocatable classrooms or relocatable modular learning spaces, which are covered by Part 2 of ANSI/ASA S12.60.

1.1.2 Acoustical performance criteria are specified in this standard by limits on the greatest one-hour average A-weighted and C-weighted background noise levels and by limits on reverberation times when students are expected to be present.

1.1.3 The control of background noise levels in this standard is achieved, in part, by specifying the minimum outdoor-to-indoor transmission class (OITC) ratings and sound transmission class (STC) ratings, depending upon the sound source, to reduce noise that intrudes into the classroom or learning space from sources outside of the building envelope, and specifying minimum STC ratings for walls and floor-ceiling assemblies where noise that originates within the school building intrudes into the classroom through classroom walls and floor/ceiling assemblies. The control of noise from footsteps or other impacts on a floor above is achieved by specifying an impact insulation class (IIC) rating for the floor/ceiling assembly.

1.1.4 This standard applies to siting and building-design-dependent sources of intrusive noise in learning spaces in schools, including noise produced by heating, ventilating, and air-conditioning (HVAC) systems; building services; and exterior sound sources such as vehicular traffic and aircraft overflights. This standard applies to the design and performance of unoccupied spaces and does not apply to sound generated within a classroom by its occupants including voices and the sounds of classroom activities such as the moving of chairs, nor does it apply to the sound from portable or permanent built-in equipment used during the course of instruction, such as computers, as long as the equipment can be turned off in the room.

1.2 Purpose

This standard is intended to provide a minimum set of requirements, based on the best scientific evidence available at the time of publication, that can be adopted by reference to this standard and enforced by an authority having jurisdiction. This standard, in conjunction with the information provided in the annexes, is intended to help school planners and designers provide good acoustical characteristics for classrooms and other learning spaces in which speech communication is an important part of the learning process.

2 Normative references

The following referenced documents are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ANSI S1.1, *American National Standard Acoustical Terminology*

ANSI/ASA S1.13, *American National Standard Measurement of Sound Pressure Levels in Air*

ANSI/ASA S12.9-1992/Part 2 (R2008), *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 2: Measurement of Long-Term Wide-Area Sound*

ANSI/ASA S12.9-1993/Part 3 (R2008), *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 3: Short-Term Measurements with an Observer Present*

ASTM E90-09, *Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements*

ASTM E336-09, *Standard Test Method for Measurement of Airborne Sound Attenuation between Rooms in Buildings*

ASTM E413-04 (2009), *Classification for Rating Sound Insulation*

ASTM E966-04, *Standard Guide for Field Measurements of Airborne Sound Insulation of Building Façades and Façade Elements*

ASTM E1007-04e1, *Standard Test Method for Field Measurement of Tapping Machine Impact Sound Transmission through Floor-Ceiling Assemblies and Associated Support Structures*

ASTM E1332-90(2003), *Standard Classification for Determination of Outdoor-Indoor Transmission Class*

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

ANSI/Infocomm 1M-2009, *Audio Coverage Uniformity in Enclosed Listener Areas*

3 Definitions

For the purposes of this standard, the terms and definitions given in ANSI S1.1 and the following apply. The definitions of acoustical terms given here are consistent with those given in ANSI S1.1 but may be simplified for the purposes of this document.

3.1 General terms

3.1.1 classrooms and other learning spaces. Locations within school buildings where students assemble for educational purposes.

3.1.1.1 core learning spaces. Spaces for educational activities where the primary functions are teaching and learning and where good speech communication is critical to a student's academic achievement. These spaces include, but are not limited to, classrooms (enclosed or open plan), instructional pods or activity areas, group instruction rooms, libraries, offices used for educational purposes, therapy rooms, and music rooms for instruction or practice.

3.1.1.2 ancillary learning spaces. Spaces where good communication is important to a student's educational progress but for which the primary educational functions are informal learning, social interaction, or similar activity other than formal instruction. For purposes of this part, ancillary learning spaces include corridors, cafeterias, and gymnasia but do not include natatoria, auditoria, music performance spaces, teleconferencing rooms, or special education rooms such as those for severely acoustically challenged students.

3.1.1.3 relocatable classroom. Educational classroom structure that utilizes factory-built modular construction methods that can be efficiently, repeatedly transported over public roads without the removal of the floor, roof, or other significant structural modification, and that typically consists of one or two modules (units, boxes, floors), but can consist of multiple units. Relocatable classrooms are frequently called portable classrooms, temporary classrooms, mobile classrooms, or learning cottages.

3.1.2 acoustical privacy. The acoustical attenuation between spaces that is needed to prevent conversation in one space from being understood in an adjacent space.

3.2 Terms relating to acoustical performance and design

3.2.1 noise level or sound level. Terms employed interchangeably throughout this standard to represent the overall frequency-weighted sound pressure level of an airborne sound. This descriptor is used to express the strength of a sound in a manner related to how the ear perceives it. Noise level or sound level is expressed in decibels, unit symbol dB.

3.2.1.1 A-weighted sound level. Sound pressure level measured with a conventional frequency weighting that roughly approximates how the human ear hears different frequency components of sounds at typical listening levels for speech. The A-weighting (see IEC 61672-1) attenuates the low-frequency (or low-pitch) content of a sound. A-weighted sound level is expressed in decibels, unit symbol dB.

3.2.1.2 C-weighted sound level. Sound pressure level measured with a conventional frequency weighting (see IEC 61672-1) that does not significantly attenuate the low-frequency (or low-pitch) content of a sound. C-weighted sound level is expressed in decibels, unit symbol dB.

3.2.1.3 one-hour average A-weighted or C-weighted sound level. Level of the time-mean-square A-weighted or C-weighted sound pressure averaged over a one-hour period. One-hour average sound level is expressed in decibels, unit symbol dB.

3.2.2 background noise. Sound in a furnished, unoccupied learning space, including sounds from outdoor sources, building services and utilities. For the purposes of this standard, background noise excludes sound generated by people within the building or sound generated by temporary or permanent instructional equipment.

3.2.2.1 interior-source background noise. Noise from building services and utilities.

3.2.2.2 exterior-source background noise. Noise from transportation sources, such as aircraft, vehicle traffic, or from other outdoor noise sources (e.g., lawn maintenance, playground activities, or industrial sources).

3.2.3 reverberation. An acoustical phenomenon that occurs in an enclosed space, such as a classroom, when sound persists in that space as a result of repeated reflection or scattering from surfaces enclosing the space or objects in the space such as chairs, desks, or cabinets.

3.2.3.1 reverberation time. A measure of the degree of reverberation in a space and equal to the time required for the level of a steady sound to decay by 60 dB after it has been turned off. Reverberation time is expressed in seconds, unit symbol s.

3.2.4 sound absorption and reflection. Acoustical phenomena that occur whenever sound strikes a surface. For the calculation or measurement of reverberation time, absorbed sound is the portion of the sound energy striking a surface that is not returned as sound energy. Reflected sound is the remaining portion that bounces off the surface.

3.2.5 attenuation of airborne sound. A measure of the decrease in sound level when sound passes through construction assemblies between spaces within a building, or from outside to inside. Attenuation is expressed in decibels, unit symbol dB.

3.2.5.1 sound transmission class. A one-number rating of the sound-blocking ability of a partition, door, window, etc., calculated in accordance with ASTM E413 from measurements of one-third-octave band sound pressure levels and sound absorption made in a laboratory and in accordance with ASTM E90, abbreviation STC.

3.2.5.2 outdoor-indoor transmission class. A one-number rating of the sound-blocking ability of a partition, door, window, etc., calculated in accordance with ASTM E1332 from measurements of one-third-octave band sound pressure levels and sound absorption made in a laboratory and in accordance with ASTM E90, abbreviation OITC.

3.2.5.3 composite sound transmission class. When a wall or other structure is made from multiple elements (for example concrete block, door, and window), the reduction in sound level is a function of the transmission loss and the area of each of the elements.

3.2.6 structure-borne impact sound. The acoustical phenomenon of sound generation and transmission due to impacts or other interaction of objects with a structure, the most common being footsteps on a floor.

3.2.6.1 impact insulation class. Single-number rating of structure-borne noise radiated below by a floor or floor-ceiling assembly when tested in a laboratory in accordance with ASTM E492 and calculated in accordance with ASTM E989; abbreviation IIC.

NOTE 1 The IIC rating is derived from the sound pressure levels measured in the receiving room when a standard tapping machine is operating on the floor assembly above, adjusted to what they would be for a specific amount of absorption in the receiving space below.

NOTE 2 The higher the IIC rating, the lower the impact sound pressure levels.

3.3 classroom audio distribution system. A system for which the primary design goal is to electro-acoustically distribute the audio portion of curricular content throughout a learning space. This content may include, but is not limited to, live voices from teachers and peers, as well as prerecorded or streaming media content from various sources, or both. The systems are not typically designed for public address purposes (such as building-wide announcements) or for the delivery of alert or warning signals, though they may include these capabilities. Classroom audio distribution systems may also include provisions to assist persons with low-amplitude voice levels or those with certain hearing conditions.

4 Applications

4.1 The acoustical performance criteria and design requirements of this standard apply to the design and construction of all new classrooms and learning spaces as specified in 1.1.

4.2 The acoustical performance criteria and design requirements of this standard apply to major renovations as defined by the adopting authority (e.g., State or local building authority, school board, or owner).

4.3 Alterations, renovations, repairs, and maintenance that diminish the acoustical performance of existing classrooms shall not be permitted.

5 Acoustical performance criteria and noise isolation design requirements and guidelines

5.1 Introduction

Acoustical performance criteria and design requirements are contained in the following sub-clauses and were selected to provide an appropriate acoustical learning environment. The performance criteria shall apply to classrooms and other core learning spaces and to ancillary learning spaces. For purposes of design calculations and field measurements used to determine conformance to the requirements of this standard, it shall be assumed that the learning spaces are furnished consistent with their use and the building is unoccupied with doors and windows closed.

5.2 Performance criteria for background noise levels

5.2.1 Exterior-source background noise levels

5.2.1.1 The one-hour average A- and C-weighted exterior-source background noise level within the enclosed space for the noisiest continuous one-hour period during times when learning activities take place shall not exceed the limits specified in Table 1.

5.2.1.2 When transportation or military sources are the dominant noise source(s), the yearly average, one-hour, or day-night (as available) A-weighted sound level shall, where practical, be predicted using the methods and computer programs developed by the U.S. Department of Transportation or U.S. Department of Defense. These include Integrated Noise Model (INM) and Noisemap for aircraft noise, Traffic Noise Model (TNM) for road noise, and the Federal Railroad Administration procedures for rail noise. These calculated levels shall be used in lieu of measured sound levels to determine the exterior-source background noise level.

5.2.1.3 The one-hour average A- and C-weighted sound level for exterior-source background noise, if measured, shall be measured in accordance with the procedures of Annex A based on guidance in ANSI/ASA S12.9 Part 2 or ANSI/ASA S12.9 Part 3 as applicable.

Table 1 — Limits on A- and C-weighted sound levels of background noise and reverberation times in unoccupied furnished learning spaces

Learning space [a]	Greatest one-hour average A- and C-weighted sound level of exterior-source background noise [b), f)] (dB)	Greatest one-hour average A- and C-weighted sound level of interior-source background noise [c), f)] (dB)	Maximum permitted reverberation times for sound pressure levels in octave bands with midband frequencies of 500, 1000, and 2000 Hz (s)
Core learning space with enclosed volume ≤ 283 m^3 (≤ 10 000 ft^3)	35 / 55	35 / 55	0.6 s [e)]
Core learning space with enclosed volume > 283 m^3 and ≤ 566 m^3 (> 10 000 ft^3 and ≤ 20 000 ft^3)	35 / 55	35 / 55	0.7 s
Core learning spaces with enclosed volumes > 566 m^3 (> 20 000 ft^3) and all ancillary learning spaces	40 / 60 [d)]	40 / 60 [d)]	No requirement

a) See 3.1.1.1 and 3.1.1.2 for definitions of core and ancillary learning spaces.

b) The greatest one-hour average A- and C-weighted interior-source and the greatest one-hour average A- and C-weighted exterior-source background noise levels are evaluated independently and will normally occur at different locations in the room and at different times of day.

c) See 5.2.2 for other limits on interior-source background noise level.

d) See 5.2.3 for limits in corridors adjacent to classrooms.

e) See 5.3.2 for requirement that core learning spaces ≤ 283 m^3 (≤ 10 000 ft^3) shall be readily adaptable to allow reduction in reverberation time to 0.3 s.

f) The design location shall be at a height of 1 m above the floor and no closer than 1 m from a wall, window, or fixed object such as HVAC equipment or supply or return opening. See A.1.3 for measurement location.

5.2.2 Interior-source background noise levels

5.2.2.1 Limits on interior-source A- or C-weighted background noise levels from building services and utilities and calculation of HVAC noise levels

The levels of interior-source background noise shall be calculated using, as a minimum, the octave-band sound pressure levels with nominal midband frequencies from 63 Hz through 8 kHz unless the equipment rating standard specifies a different range. The calculation shall include the sound from all relevant HVAC sources and paths.

The one-hour average A- or C-weighted level of interior-source background noise shall not exceed the limits specified in Table 1. Multi-stage types of HVAC equipment may operate at multiple conditions resulting in different sound levels that contribute to the one-hour average A- or C-weighted sound level. The sound levels for the different conditions shall not exceed the limits in Table 2. The noise level of the different operational conditions, if measured, shall be measured in accordance with the procedures of Annex A. The one-hour average A- or C-weighted sound levels of any other building system sounds (e.g., lighting) for which sound power data are available, shall be combined on time-mean-square basis with the calculated one-hour average A- or C-weighted sound level of the HVAC noise before determining conformance. Where sound power data are not available, estimated one-hour average A- or C-weighted sound levels shall be used.

Table 2 — Limits on one-hour average A- and C-weighted sound levels (designated by X / Y below) from sources associated with building services and utilities

Room type	HVAC operating condition	Building services [a] sound level limits (dB) [c) d)]	
		Single mode HVAC Type 1	Multiple mode HVAC Type 2
Core learning space	Design or maximum capacity heating or cooling	35 / 55	37 / 57
	Reduced or low capacity heating or cooling or ventilation [b]	Not applicable	34 / 54
Ancillary space	Design or maximum capacity heating or cooling	40 / 60	42 / 62
	Reduced or low capacity heating or cooling or ventilation [b]	Not applicable	39 / 59

Type 1 - represents systems that have a single operational mode of performance.

Type 2 - represents systems that have multiple stages of cooling or heating, multiple or variable fan speeds, or ventilation-only modes.

[a] The level for HVAC sound shall be combined with the level of the sound from other building systems such as lights, plumbing, etc., if applicable. If present, the contribution of an outdoor condenser or chiller to the classroom sound level shall be combined with the sound from other building services.

[b] The operating condition is one that occurs frequently and represents airflow less than design or reduced refrigeration capacity or both.

[c] The HVAC design location shall be at the loudest position that is at a height of 1 m above the floor and no closer than 1 m from a wall or fixed object such as HVAC supply or return opening.

[d] An HVAC unit designed to provide climate control and ventilation for individual classrooms that conforms to the 35 dB hourly equivalent level requirements of ANSI/ASA S12.60 Part 2 shall be considered to conform to the requirements of ANSI/ASA S12.60 Part 1.

5.2.2.2 Limits on disturbing sounds from building services and utilities

Disturbing tonal sounds, such as hums, buzzes, whines, or whistles generated by HVAC systems and other building services and utilities shall be controlled so as to not interfere with speech communication or be distracting or annoying to the occupants of the learning spaces. Such sounds, if any, that were not able to be controlled during the design process shall be mitigated after construction. The prominence of any tonal sounds shall be quantified using the methods in ANSI/ASA S1.13, and there shall be no "prominent discrete tones" as defined in ANSI/ASA S1.13.

5.2.3 Background noise in corridors

When corridors adjacent to classrooms are used solely for conveyance of occupants within the school building and structured learning activities do not occur there, the one-hour average A-weighted background noise level in such corridors shall not exceed 45 dB.

5.2.4 Equipment, machinery, and components associated with instruction

The limits on background noise level established in 5.2.1 through 5.2.3 do not apply to portable or permanent (built-in) equipment, machinery, and components associated with instruction, such as computers, audiovisual equipment, shop machinery, fume hoods, kitchen exhaust, and similar devices provided such equipment can be turned off from within the learning space. Calculations of background noise level shall not include such equipment and all measurements shall be made with such equipment and emergency equipment turned off. Calculations of background noise level shall include all equipment that cannot be turned off from within the learning space except for emergency equipment.

5.3 Performance criteria for reverberation times

5.3.1 The reverberation times shall conform to the limits specified in Table 1.

5.3.2 Core learning spaces ≤ 283 m^3 (≤ 10 000 ft^3) shall be readily adaptable to allow reduction in reverberation time to 0.3 s. A classroom is readily adaptable if it can be readily improved through adding the required sound absorption as calculated with the Sabine equation (Equation 1). According to this formula, the minimum total sound absorption *A* needed to achieve a reverberation time of T_{60} seconds or less in a room of enclosed volume *V* is given by:

$$A \geq kV / T_{60} \qquad (1)$$

The constant k = 0.161 s/m when volume *V* is in cubic meters and the sound absorption *A* is in square meters. Constant k = 0.049 s/ft when volume *V* is in cubic feet and sound absorption *A* is in square feet.

It shall be shown, or be readily apparent, that available surface area to add new sound absorptive materials (carpet, wall panels, etc.) on existing sound reflective finishes and/or additional sound absorption from improving readily upgradable existing acoustical finishes, such as replacing ceiling panels, are together adequate to provide the required sound absorption. For purposes of this standard, no further calculations are required if it can be shown that the area of reflective wall or ceiling area readily available for adding sound absorptive finishes is at least the lesser of 80 m^2 or 0.28 V m^2 where *V* is the room volume in m^3 (860 ft^2 or 0.086 V ft^2 where *V* is the room volume in ft^3).

5.4 Noise isolation design requirements

5.4.1 Outdoor-to-indoor attenuation of airborne sound

5.4.1.1 The background noise level inside classrooms from exterior sources is a function of two independent factors: (1) the exterior noise environment, and (2) the reduction of the exterior noise from outdoors to indoors by the building shell. It shall be the responsibility of the user, e.g., the school board, to determine and specify the site exterior noise environment which is the one-hour average A-weighted sound level for the noisiest hour on the average (school) day during school hours. To this end, the user shall conduct a site assessment to determine the greatest outdoor one-hour average A-weighted sound level at the proposed location of the classroom or other core learning space.

5.4.1.2 In addition to the requirement of 5.2.1.1 to reduce the one-hour average interior A-weighted sound levels below 35 dB and the corresponding one-hour average C-weighted sound levels to less than 55 dB, all newly constructed core learning spaces shall be designed to conform to a minimum Outdoor-Indoor Transmission Class (OITC) shown in Table 3. Where a wall contains windows, doors, or penetrations for ventilation, the composite structure, including the window, doors, or penetrations, shall conform to the OITC requirement.

5.4.1.3 When there is an exterior walkway within 3 m (10 ft) or a playground within 9 to 15 m (30 to 50 ft) of the exterior wall of a core learning space, the basic wall shall have an STC rating of at least 45 and exterior doors shall have an STC rating of at least 30. If there are windows in such a wall within 3 m (10 ft) of an exterior walkway or within 9 to 15 m (30 to 50 ft) of a playground, the composite STC rating of the wall including the windows and doors shall be at least STC 40. If a playground is closer than 9 m (30 ft) to the wall of a core learning space, the composite STC rating of the exterior wall shall have a rating of at least STC 50, except that this requirement shall not apply where the playground is dedicated for use only by the adjacent learning space and will therefore not be active while learning activities are occurring in the core learning space.

5.4.1.4 Verification measurements, if required, shall be performed in accordance with the procedures in Annex A.

Table 3 — Minimum OITC rating for core learning spaces

A-weighted outdoor noise level (dB) [a), b)]	OITC rating walls with windows	OITC rating roofs and walls without windows
<55	30	36
56	31	37
57	32	38
58	33	39
59	34	40
60	35	41
61	35	41
62	36	42
63	37	43
64	38	44
65	39	45
66	39	45
67	40	46
68	41	47
69	42	48
70	43	49
71	43	49
72	44	50
73	45	51
74	46	52
75	47	53
76	47	53
77	48	54
78	49	55
79	50	56
80	50	56
>80	Not permitted	Not permitted

[a)] See 5.4.1.1.
[b)] See 5.2.1.

5.4.2 Indoor-to-indoor attenuation of airborne sound

5.4.2.1 Wall and floor-ceiling assemblies that separate enclosed or open-plan core learning spaces from adjacent spaces shall be designed to achieve the minimum STC ratings specified in Table 4. The STC rating requirements of Table 4 also shall apply to the design of temporary partitions that subdivide a learning space.

Table 4 — Minimum STC ratings required for single or composite wall and floor-ceiling assemblies that separate a core learning space from an adjacent space

Adjacent space			
Other enclosed or open-plan core learning space, therapy room, health care room and space requiring a high degree of acoustical privacy [a), b)]	**Common-use and public-use toilet room and bathing room** [a)]	**Corridor, staircase, office, or conference room** [c), d)]	**Music room, music performance space, auditorium, mechanical equipment room,** [e)] **cafeteria, gymnasium, or indoor swimming pool.**
50	53	45	60

a) These requirements do not apply to toilets opening only into the core learning space and used only by occupants of the core learning space.

b) A 20 cm (8") concrete masonry unit wall having a surface weight density of at least 180 kg/m^2 painted and sealed on both sides, acoustically sealed at the entire perimeter and extending from the floor slab to the structural deck above, is an acceptable alternate assembly that conforms to the intent of 5.4.2.1.

c) For corridor, office, or conference room walls containing doors, the basic wall, exclusive of the door, shall have an STC rating as shown in the appropriate column in this table. The entrance door shall conform to the requirements of 5.4.2.4.

d) When acoustical privacy is required, the minimum composite STC rating, including the effects of doors, of the partitions around an office or conference room, shall be increased to 50.

e) The isolation between core learning spaces and mechanical equipment rooms shall have a STC rating of 60 or greater unless it is shown that the sound level in the mechanical equipment room combined with a lower STC rating can achieve the required sound level in the core learning space. In no case shall the design STC between such spaces be less than 45.

5.4.2.2 All penetrations in sound-rated partitions shall be sealed and treated as necessary to achieve the required STC ratings. Attention shall be given to flanking paths that would reduce the isolation between spaces.

5.4.2.3 For walls containing doors between a core learning space and corridors or stairwells, the minimum STC ratings of Table 4 apply to the wall exclusive of the door. For walls containing doors between a core learning space and offices, conference rooms, or toilets that open only to the one core learning space, the minimum STC ratings of Table 4 apply to the wall exclusive of the door. In all other cases, the STC rating applies to the composite construction including the effects of doors, windows, penetrations, etc.

5.4.2.4 Interior door assemblies and up to 1 m^2 (10 ft^2) of window glazing area immediately adjacent to the door opening into core learning spaces from corridors, stairways, offices, or conference rooms shall achieve a STC rating of 30 or greater in their operable condition. The STC rating for interior entry doors into music rooms from corridors or staircase areas shall be at least 40 if such doors are within 9 m (30 ft) of a door to a core learning space. A vestibule entry composed of two sets of doors with STC ratings of 30 or greater shall be considered to conform to the STC 40 requirement.

5.4.2.5 It shall be the responsibility of the user, e.g., the school board, to determine if and when an office or conference room needs to have a high degree of acoustical privacy. If so, then the STC rating between these specifically designated spaces and adjacent spaces shall be at least 50.

5.4.2.6 Verification measurements, if required, shall be made in accordance with the procedures in Annex A.

5.4.3 Structure-borne impact sound isolation

The floor-ceiling assemblies of normally occupied rooms located above learning spaces shall be designed for a laboratory test rating of at least IIC 45 if they are located above core learning spaces and IIC 40 if they are located above ancillary learning spaces. These IIC ratings shall apply without carpeting on the floor in the room above the learning space. In new construction, gymnasia, dance studios, or other rooms with high floor-impact activity shall not be located above classrooms or other core learning spaces. In renovations, existing gymnasia, dance studios, and similar rooms with high floor-impact activity when it is located above core learning spaces shall either be relocated or the IIC rating of the separating floor-ceiling assembly shall be at least 70 when located above a core learning space with an enclosed volume not greater than 566 m^3 (20 000 ft^3); at least 65 when located above a core learning space with an enclosed volume greater than 566 m^3 (20 000 ft^3); and at least 65 when located above an ancillary learning space.

5.5 Classroom audio distribution systems

5.5.1 Uniformity of coverage

Classroom audio distribution systems, if installed, shall not be used as a substitute for achieving the acoustical design requirements of this standard. Such systems, if installed, shall have uniform coverage within ±2.5 dB for octave-band sound pressure levels with midband frequencies of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. Measurements of the coverage uniformity, if performed, shall be conducted in accordance with the measurement procedures contained in ANSI/INFOCOMM 1M-2009.

5.5.2 Limitations on sound intrusion into adjacent learning spaces

Classroom audio distribution systems shall be adjustable so that their sound output can be reduced to levels such that the sound from the system does not intrude on adjacent learning spaces.

5.6 Conformance testing

This standard does not require testing to demonstrate conformance. When optional tests are performed to verify conformance to the requirements of this standard, the procedures in Annex A shall be followed.

NOTE If the school is a prototype design that will be repeated at multiple sites, it is recommended that conformance testing be undertaken on the first structure.

Annex A

(normative)

Verification of conformance by measurement

A.1 Verification of conformance with interior-source background noise requirements

A.1.1 Interior-source background noise level measurements shall be taken during time periods when the outdoor sound contribution to the indoor sound is minimal. Both background measurements and HVAC measurements shall be taken under nominally the same outdoor environment.

A.1.2 Identify the listening area within the classroom where direct teacher and student speech communication generally takes place. With the HVAC and other noise sources operating in their respective design operational modes, perform an acoustical survey of the classroom within that listening area. This survey shall be done at what are potentially the noisiest locations within the room, including at the HVAC inlet or outlet air ducts, in the vicinity of the HVAC equipment, or at any other location that the observer identifies as a significant source of interior-generated noise. Identify the noisiest location within the listening area using a sound level meter that conforms to the requirements for either Class 1 or Class 2 performance as specified in IEC 61672-1. The meter shall have a minimum frequency range encompassing the octave bands from 63 Hz to 8 kHz. The location with the highest A-weighted sound level shall be termed the “key” location.

A.1.3 Measurements, including the above screening for the "key" location, shall be taken at any time such that outdoor noise levels (except for HVAC equipment such as condensing sections or chillers) are at least 6 dB below the interior-source noise levels; that is, they contribute less than 0.5 dB to the measurement of the interior source background noise. The microphone shall be located at a height of 1.0 to 1.2 m (40 to 48 in.) above the floor and no closer than 1 m (40 in.) from a wall, fixed object such as HVAC plenum, or bookshelves, and no closer than 0.5 m (20 in.) from a readily movable object such as a desk, chair, or table.

A.1.4 At the key location, first measure the sound with the HVAC equipment turned off. Then take five consecutive A- and C-weighted 60-second time-averaged sound level measurements with the HVAC operating. If each of the measured A- and C-weighted levels with HVAC equipment operating is at least 6 dB higher than the background A- and C-weighted levels, respectively, then the HVAC noise shall be considered to be the primary source of interior noise. If the HVAC sound is the primary source of interior-generated noise, then the steadiness of the noise shall be determined following the procedure in A.1.6.

A.1.5 For heat pump systems, the sound testing shall be performed in the cooling mode if the outdoor ambient temperature is 10° C (50° F) or above and in the heating mode if the outdoor ambient temperature is below 10° C (50° F). For fuel furnaces and compressor cooling systems, the sound testing shall be performed in the cooling mode.

A.1.6 The average of five consecutive 60-second measurements in each mode of operation shall be recorded. For each mode, it shall be determined if the background sound levels are steady. The criterion for steady background sound levels shall be that the difference between the highest and lowest data sound levels of the five 60-second samples is not more that 3 dB.

A.1.7 If the background noise level is steady, then measurements shall be repeated in each operational mode of the HVAC equipment and the sound levels shall be compared to the limits in Table 2.

A.1.8 If the background noise level is unsteady, then the source of the unsteadiness shall be determined—exterior or interior.

A.1.8.1 If the source is exterior, then the interior-source background noise measurements shall be repeated at a time when the exterior noise is less. If no such time can be found, then it is likely that the outdoor sound is too great and it shall be measured and conformance verified for exterior-source background noise by the procedure in A.2.

A.1.8.2 If the source is interior, then one-hour average A-weighted sound level measurements including operation at both design conditions and other typical conditions shall be taken and reported. These measurements shall be used in lieu of the five 60-second averages to determine the interior-source background noise level for the room at the key location. The one-hour measurements shall be compared to the limits in Table 2.

A.1.9 Measured sound levels within 2 dB of the background noise criterion shall be reported as conforming to the background noise criterion.

A.2 Verification of conformance to the exterior-source background noise requirement

A.2.1 Verification of conformance with the outdoor-to-indoor noise level reduction requirement

A.2.1.1 The outdoor-indoor noise isolation class (OINIC) shall be measured in accordance with the procedures of ASTM E966.

A.2.1.2 If present with sufficiently high sound level, the actual major outdoor noise source (e.g., aircraft, road or rail traffic, industrial noise) may be used for the OINIC measurements at a specific application site; otherwise, an artificial noise source(s) shall be used.

A.2.1.3 The OINIC shall always be measured for a wall with windows. If the only wall with windows is shielded from direct exposure to the dominant exterior source sound, and a roof or another wall without windows is exposed to the dominant exterior source sound, then the OINIC shall also be measured for the roof or wall without windows.

A.2.1.4 Where a requirement exists for a wall or room to conform to a specified OITC, a measured OINIC for that wall or room within 3 points of the specified OITC shall be considered as verifying the specified performance.

A.2.2 Determining or verifying the user-stipulated exterior-source, outdoor, free-field, loudest-hour environmental noise levels

A.2.2.1 The one-hour average A-weighted sound levels shall be measured in accordance with ANSI/ASA S12.9 Part 2 and ANSI/ASA S12.9 Part 3, as applicable, and in accordance with ANSI/ASA S1.13. Extraordinary sounds such as a vehicle crash, a loud airplane where normally there are none, or siren where normally there are none, shall be excluded from the reported hourly environmental noise level.

A.2.2.2 Sound levels within 2 dB of a previously estimated and stipulated one-hour average A-weighted sound level shall be considered as verifying conformance to the estimated and stipulated result.

A.2.3 Overall outdoor-to-indoor tolerance

The sum of the deviations reported for A.2.1.2 and A.2.2.2 shall be ≤ 2 dB.

A.3 Verification of conformance to the inside-to-inside sound isolation requirements

A.3.1 Verification of inside-to-inside airborne sound isolation

A.3.1.1 The noise isolation class (NIC) between rooms shall be measured in accordance with the procedures in ASTM E336.

A.3.1.2 Where a requirement exists for isolation to conform to a specified STC, a measured NIC within 3 points of the specified STC shall be considered as verifying conformance to the specified performance.

A.3.1.3 In some cases walls containing doors and windows, such as corridor walls, are exempt from the overall STC requirement as affected by the doors and windows. For these cases calculate the composite STC based on the expected STC of the various elements such as wall, doors, and windows and their respective areas. To determine conformance, compare the composite STC with a measured NIC.

A.3.2 Verification of inside-to-inside impact sound isolation

A.3.2.1 The apparent impact insulation class (AIIC) shall be measured in accordance with the procedures in ASTM E1007.

A.3.2.2 A resulting AIIC within 5 points of the specified IIC shall be considered as verifying conformance to specified performance.

A.4 Verification of conformance to reverberation time requirements

Conformance with the reverberation time requirements of this standard may be verified by either of the two options below.

1) Calculation option: Absorption coefficients shall be provided in octave bands with mid-band frequencies of 500, 1000, and 2000 Hz for surface material and acoustic treatments used within the space. Using these absorption coefficients and the room dimensions, the Sabine equation [Equation (1)], shall be used to calculate conformance to the standard. These calculations are required during the design phase and may be used to demonstrate conformance.

2) Measurement options: If field measurements are made to demonstrate conformance, the methods described in ASTM E2235-04 and ISO 3382-2 can be referred to for general guidance on the test method. In either case, the following requirements shall be met. When using the interrupted noise method to obtain decays, a minimum of five decays shall be measured at each measurement position. These measurements shall be repeated for at least six combinations of three microphone positions and two source positions. If the integrated impulse response method (described in ISO 3382-2) is used to obtain the decays, there is no need for repeated decays at each measurement position. However, measurements shall be made for a minimum of the six combinations of three microphone positions and two source positions.

The use of an approximately omni-directional loudspeaker source is preferred, but other types of loudspeakers may be used including corner loudspeakers and loudspeakers with directionality similar to a human talker. In all cases the source-to-receiver distance shall not be less than 1/3 of the largest dimension of the room.

If omni-directional or human-simulating sound sources are used, they shall be placed at positions that are typical for teachers and/or students when they are speaking to the class. Microphone locations shall be selected from locations where student listeners typically would be located.

Measurements shall be at a minimum for the octave bands including 250 Hz through 4000 Hz.

In determining the decay rate, the calculation shall begin with the first point of the decay that is more than 5 dB below the level when the sound was on.

A measured reverberation time ± 0.1 s shall be considered to conform to this standard.

A.5 Terms and definitions used in Annex A

A.5.1 apparent impact insulation class (AIIC). Single-number rating of the structure-borne noise radiated below by a floor or floor-ceiling assembly when tested in the field in accordance with ASTM E1007 and calculated in accordance with ASTM E989.

NOTE 1 The rating is derived from the sound pressure levels measured in the receiving room when a standard tapping machine is operating on the floor assembly above, adjusted to what they would be for a specific amount of absorption in the receiving space below.

NOTE 2 The higher the AIIC rating, the lower the impact sound pressure levels.

NOTE 3 AIIC is sometimes also referred to as "field impact insulation class" or FIIC.

A.5.2 noise isolation class (NIC). A one-number rating of the attenuation of airborne sound between enclosed spaces calculated in accordance with ASTM E413 from one-third octave band sound levels measured in accordance with ASTM E336 or from the attenuation of airborne sound calculated between the spaces during design.

A.5.3 outdoor-indoor noise isolation class (OINIC). A one-number rating of the attenuation of airborne sound between the outdoors and inside a building calculated in accordance with the procedures of ASTM E1332 from one-third octave band sound levels measured in accordance with ASTM E966 or from the attenuation of airborne sound from outdoors to indoors calculated during design.

NOTE The measured or calculated attenuation of airborne sound between the outdoors and indoor spaces is substituted for the ASTM E90 data in the calculation method of E1332 to calculate the OINIC.

Annex B

(informative)

Commentary on specific paragraphs of this standard

Commentary-1.1.1. Special-purpose classrooms such as teleconferencing rooms, special-education rooms such as those for students with hearing and listening impairments, or other spaces such as large auditoria may have unique acoustical requirements that are different than the minimum requirements set forth in this standard. Requiring conformance to the minimum requirements of this standard therefore may not be suitable or appropriate for such rooms. While these spaces are exempt from the minimum requirements of this standard, designers are expected to consider and design for the unique acoustical requirements of these spaces.

Commentary-1.1.2. An objective of these performance criteria is to achieve a level of speech that is sufficiently high relative to the background noise level for listeners throughout the classroom or learning space. However, a requirement for the relative difference between speech levels and levels of background noise, usually referred to as the signal-to-noise ratio, is not within the scope of this standard.

Commentary-1.1.4. The background noise generated by occupants and instructional equipment can seriously degrade communication or speech intelligibility in learning spaces. This evaluation should be made to aid in the application of practical noise control measures for school designers or staff. The measures may take the form of using neoprene chair-leg tips to minimize the sound of scuffling chairs and avoiding locating noisy projectors close to students.

Commentary-3.2.3.1 reverberation time. The decay rate depends on the amount of sound absorption in a room, the room geometry, and the frequency of the sound. In practice, the reverberation time is often measured by measuring the time required for a 20 or 30 dB decay and extrapolating that decay rate to the time required for a 60 dB decay.

Commentary-3.2.4 sound absorption and reflection. The level of a reflected sound in a room is determined by the amount of sound absorption at the surfaces, the room geometry, and the frequency of the sound. As the distance between a sound source and a receiver in a classroom increases, the sound at the position of a receiver is increasingly dominated by reflected sound.

Commentary-3.2.5 attenuation of airborne sound. The attenuation of airborne sound depends on the sound reduction through these elements, on their size, on sound leakage around their periphery, on the sound absorption in the receiving space, and on the frequency of the sound.

Commentary-3.2.5.3 composite sound transmission class. Elements with very little transmission loss, such as openings or holes, reduce the effective transmission loss of the composite wall. The reduced effectiveness can be observed even when the opening is a small percent of the total wall, and may not be significantly increased by the greater sound transmission loss of the remaining elements of the wall.

Commentary-4.1. Conformance to the requirements and guidelines of this standard should be considered to be a minimum goal for the acoustical qualities of such spaces, excluding auditoria. The standard does not provide recommendations for electronic aids for persons with hearing impairment, though conformance to this standard will help ensure effective application of such aids.

Commentary-4.2. During renovation of some facilities, it may not be practical to achieve the targets for sound levels or transmission loss. In those cases, the intent of this standard should be followed to the extent practical.

Commentary-5.2.2.1 Limits on interior-source A- or C-weighted background noise levels from building services and utilities and calculation of HVAC noise levels. The HVAC noise analysis should:

- Follow accepted methods or ones that have been demonstrated to produce equivalent results.
- Consider all relevant sound sources and propagation paths.
- Include at a minimum, octave-band sound pressure levels with nominal midband frequencies from 63 Hz to 8 kHz. Occasionally, industry specifications or rating standards do not include octave band data for some equipment types for which these data are not usually a concern. Professional judgment is needed to apply these data properly. The method should include effects from all relevant HVAC sound sources and propagation paths.
- Consider all relevant modes of operation.

A common method for HVAC noise analysis that has been shown to be acceptable is provided in the ASHRAE Applications Handbook. This document is regularly updated to include current practices and scientific evidence of acoustical effects in HVAC systems.

Commentary-5.2.2.2 Limits on disturbing sounds from building services and utilities. The tonal content of pure tones, hisses, hums, and buzzes can be distracting and impair speech communication and learning. Low-frequency sound at high levels can be distracting and cause rattles. The C-weighted sound level is indicative of whether the low-frequency sound levels are high enough to cause a problem. Other methods to quantify this effect are also available. The rumble description from the ANSI/ASA S12.2 Annex D RC Mark II is a useful metric for determining if the sound would be acceptable and will augment the use of C-weighted sound levels.

Commentary-5.2.4 Equipment, machinery, and components associated with instruction. Control of noise from such sources, especially from permanent built-in instructional equipment, should be carefully addressed in the planning stages for new and renovated schools.

Commentary-5.3.1. A reverberation time of 0.3 s, shorter than stated in Table 1, is necessary for children with hearing impairment and/or other communicative issues. Reducing the background noise to the level required in Table 1, while of benefit, is not sufficient for these children unless reverberation time is also reduced to 0.3 s. The children need both a reduced reverberation time (0.3 s) and high speech-to-noise ratios in order to access the curriculum and classroom instruction.

Commentary-5.3.2. The sound absorption coefficient of a material normally varies with frequency. It ranges from about 0.2 to about 1.0 for sound-absorbing materials, to less than 0.05 for a smooth, painted concrete floor. Sound absorption coefficients measured in a laboratory (that is, in a reverberation room) can be larger than 1.0 because of test method and sample size effects.

Commentary-5.3.2. One possible method to readily permit further reduction in reverberation time to 0.3 s in a core learning space may be the installation, at the time of the initial construction or major renovation, of hardware (e.g., hooks) in the ceiling or on walls that facilitate installation of additional or more-acoustically absorbent materials, or both.

Commentary-5.4 Noise isolation design requirements. The first and most cost-effective step in achieving good noise isolation between learning spaces and other spaces in a school is accomplished in the facility planning stage. This planning includes optimizing the location of noisy spaces and activities to protect sensitive learning spaces. Where such locations are not possible, adequate noise isolation is needed.

Commentary-5.4 Need for noise isolation. The acoustical performance criteria for background noise levels in 5.2 apply to unoccupied facilities. However, in occupied facilities, activity noises generated in one space can be transmitted through walls, floors, ceilings, and doors to adjacent learning spaces, thus contributing to the overall background noise level in those spaces. Adequate sound isolation is required to limit noise transmission between core learning spaces and adjacent spaces in occupied facilities. The minimum STC ratings of Table 4 are intended to provide this noise isolation for normal activities in adjoining spaces. Certain educational styles (such as open plan and group learning) intentionally avoid the use of full enclosures between learning groups. Sometimes, partial-height sound barriers or no barriers at all separate adjacent learning groups. Adequate noise isolation between adjacent learning groups cannot be assured unless each learning group is fully enclosed by ceiling-height sound barriers. Because of the inherent low noise isolation, partially enclosed or unenclosed learning spaces are not recommended when good speech communication is desired. In occupied multistory educational facilities, the transmission of impact noise through the floor of the room above to the learning space below also contributes to the overall background noise level. To limit impact noise disturbances in learning spaces, this standard also provides minimum impact insulation class (IIC) design requirements for the floor-ceiling assemblies above learning spaces for multi-story educational facilities.

Commentary-5.4 Caution on variability of sound isolation test results. When walls or floor-ceiling assemblies are tested in a laboratory, the STC ratings of individual samples may vary widely. A single test result can be misleading. With a large enough sample set, a typical or expected result can be established. To determine if a given assembly will conform to the requirements of this standard, the user should not rely on a rating that is significantly different from the ratings for similar assemblies unless statistical information is available to show that the assembly is within accepted variation.

Likewise, there is a variation when noise isolation class (NIC) tests are conducted in the field. The apparent performance of the partition in the field is virtually always less than the acoustical performance of a similar partition in a laboratory. The difference is a result of flanking around the partition and possibly lesser quality construction.

Flanking between adjacent classrooms can reduce the isolation between spaces if gaps or cracks exist. Attention should be given to preventing surfaces such as side walls, floors, or ceilings from being continuous from one classroom to another.

Commentary-5.4.1 Outdoor-to-indoor attenuation of airborne sound. The level of outdoor sound should be predicted, when possible, for the sound that impinges on each façade of the school, and the layout optimized for minimum noise intrusion. For example, next to a highway, one could locate swimming pools, gymnasia, and cafeterias on the side of the structure facing the highway with classrooms facing away from the highway. The natural shielding of the building would then assist in protecting the classrooms from intruding outdoor noise. Because of the shielding provided by the building, the acoustical design requirements of the exterior classroom wall might be reduced.

Commentary-Table 3. The requirements of Table 3 provide a margin of at least 5 dB at the lower sound levels to allow for potential future growth of noise levels.

Commentary-5.4.2.1. Recommendations are given in Table B.1 for STC ratings for isolation of ancillary spaces from one another or from other spaces.

Table B.1 — Minimum STC ratings recommended between an ancillary space and an adjacent space

Receiving ancillary learning space	Adjacent space			
	Corridor or staircase [a)], common-use, and public-use toilet and bathing room [b)]	Music room	Office or conference room [a)]	Mechanical equipment room [f)], cafeteria, gymnasium, or indoor swimming pool
Corridor used as ancillary learning space	45	60[c)]	45[d)]	55[c)]
Music room	45	60	60[e)]	60
Office or conference room	45 [d)]	60[g)]	45[d)]	60

a) For corridor, staircase, office or conference room walls containing entrance doors to the ancillary learning space, the STC rating of the basic wall, exclusive of the door, should be 45. The entrance door should conform to the requirements of 5.4.2.4.

b) The STC rating for an ancillary space/toilet partition does not apply when the toilet is private and connected to a private office. An STC rating greater than 45 may be required for separating a quiet office or conference room from a common-use or public-use toilet or bathing room.

c) When the corridor will not be used as an ancillary learning space, the minimum STC rating may be reduced to not less than 45. Use of corridors as ancillary learning spaces should be avoided when they are located next to the noisy spaces indicated in the table by the high STC ratings.

d) When acoustical privacy is needed for conversations in an office or conference room, the minimum rating should be a composite STC of 50 instead of 45 that includes the effects of any doors or windows etc.

e) An STC rating of 60 is justified to prevent the music space from interfering with hearing in the office or conference room.

f) Isolation between ancillary learning spaces and mechanical equipment rooms is dependent on the noise level in the mechanical equipment room and can be less than STC 60 in some cases but should never be less than STC 45.

g) The STC rating of 60 does not apply when the office is for the music teacher and opens to the music room.

Commentary-5.4.2.3. Composite assemblies are walls, floor-ceiling and roof-ceiling constructions composed of more than one element (for example, a wall with a door, window, or penetrations by HVAC ducts or other services). This standard requires that walls between core learning spaces conform to the composite STC requirement, which means that any door in such a wall will need to be acoustically rated. See 5.4.2.3 for special requirements for doors in corridor, office or conference room walls that are not required to conform to the STC requirements for composite walls including the doors. Walls and floor-ceiling assemblies may not maintain their design STC rating if penetrations or openings for piping; electrical devices; recessed cabinets; soffits; or heating, ventilating or exhaust ducts are unsealed.

Commentary-5.4.2.4. The intent of the STC 30 requirement is to require solid core wood doors or heavy-duty steel doors with good seals. The location of classroom entry doors across a corridor should be staggered to minimize sound transmission between these classrooms. Provisions should be made to ensure that the perimeter seals of sound-rated doors are well maintained. Seals for entrance doors should be inspected and adjusted, as necessary, every six months. Gaskets of door seals should never be painted.

Commentary-5.4.3 Structure-borne impact sound isolation. There is no way to analytically predict an IIC rating. Structures have to be tested. Very little if any test data are available for classroom type structures. Almost all test data are for residential structures with gypsum ceilings. Achieving this rating with frame-type construction usually requires an isolated gypsum ceiling and a cushioning agent under a hard surface floor or the use of carpet. This standard requires conformance to the IIC requirements without carpet even if carpet is to be used.

Commentary-5.5 Classroom audio distribution systems. It is likely that many, if not most, classrooms will be built with, or at some time have, audio distribution systems. Built-in systems with uniform coverage as required in 5.5.1 used for speech and incidental music or video, and with proper gain and bass settings, should not be heard in neighboring classrooms.

The bass sounds of music or multimedia presentations frequently are a particular problem to neighboring classrooms. To further control this “neighboring classroom” noise problem, it is recommended that classroom audio distribution systems contain automatic limiting circuitry to control the system gain and limit the audio volume. In some situations walls with an STC rating greater than 50 may be required.

Commentary-A.1 Verification of conformance with interior-source background noise level requirements. If the contribution of outdoor sound to the measurement of indoor sound levels cannot be reduced during the available measurement period, a second sound level meter should be placed outside the room under test to measure the exterior noise simultaneously. The exterior-to-interior noise reduction should then be measured simultaneously for the sequential measurements of ambient sounds. Then when measuring with the HVAC system ON, the ambient noise level can be deduced using the exterior noise level and the previously determined noise reduction.

Annex C

(informative)

Design guidelines for controlling reverberation in classrooms and other learning spaces

C.1 Introduction

The amounts and locations of sound-absorbing treatments that may be needed to limit reverberation are important considerations for good acoustical characteristics in learning spaces. Excessive reverberation can reduce the understanding of spoken words. Conversely, too much sound-absorbing treatment, especially in dedicated lecture rooms, can reduce beneficial early sound reflections causing speech levels from a talker to fall off rapidly with distance and thereby reduce speech intelligibility for distant listeners. This annex provides design guidelines for the control of reverberation in learning spaces by the addition of sound-absorbing materials. The guidelines are intended to assist in achieving conformance to the reverberation time criteria in Table 1 as well as 5.3.2.

C.2 Procedure to estimate the amount of sound-absorbing material needed to achieve the design goal for reverberation time

The first step in developing an estimate of the minimum required area of acoustical treatment for installation in a learning space is to apply the Sabine equation [Equation (1), located in Clause 5.3.2].

Next, the total sound absorption is broken down into the sum of the products of the surface area S_i of each such sound-absorbing surface and the sound absorption coefficient α_i for this surface. That is, the total sound absorption A is given by the summation over all treated surfaces as expressed by the following relation:

$$A = \alpha_1 S_1 + \alpha_2 S_2 + \alpha_3 S_3 + \bullet\bullet\bullet\bullet + \alpha_i S_i + A_R \quad \text{(C.1)}$$

where A_R is the residual sound absorption. A default value of A_R equal to 15% of the floor area accounts for the acoustically untreated room surfaces (for example, the untreated walls, ceiling, and bare, uncarpeted floor) and for the furnishings (for example, tables, chairs, desks, and shelves [see C.3.4]). For a carpeted room, a value for A_R, of 20% of the floor area is recommended as a conservative default design value to calculate the total absorption A.

Alternatively, the designer can set A_R equal to 13% of the floor area plus the product of the carpet surface area and its sound absorption coefficient. The latter may vary from a minimum of less than 0.1 at 500 Hz to as high as 0.65 at 2000 Hz, depending on the type and thickness of the carpet and its underlayment. Many references, such as those listed in the bibliography to this annex, provide tables of sound absorption coefficients for different acoustical materials, including carpet, at different frequencies.

These same references may be used to provide alternative sound absorption coefficients for other surfaces in place of the preceding default assumptions. Tabulations of the sound absorption per table or chair are available from these references. Their coefficients may be used if these furnishings are comparable to those intended for the learning space.

For best accuracy in calculations of reverberation time, it is recommended that laboratory-certified sound absorption coefficients be used. These are normally available from acoustical material manufacturers (see C.2.1).

Next, the values of α_i and S_i for the proposed materials and surface areas are substituted into Equation (C.1). If necessary, the choices of material and material areas are adjusted until Equation (1) is satisfied. The minimum total sound absorption is calculated from application of Equation (1) for frequencies of 500 Hz, 1000 Hz, and 2000 Hz and the applicable target reverberation time from Table 1.

The process described above can be simplified substantially when only one type of sound-absorbing material is to be installed and A_R is assumed to be 15% of the floor area.

The volume V of the learning space can be expressed as the product of floor area S_f and average ceiling height H. Using Equations (1) and (C.1) and a residual absorption of 15% of the uncarpeted floor area, it is straightforward to construct a table of the minimum required surface area S_1 as a percentage of the floor area for maximum reverberation times of 0.6 s and 0.7 s from Table 1. The variables in the table are the sound absorption coefficient α_1 of the acoustical treatment and average ceiling height H.

With the assumptions described above, the entries in Table C.1 for the minimum surface area of acoustical treatment S_1 as a percentage of floor area S_f were calculated from the following expression.

$$100\ (S_1 / S_f) \geq 100\ \{[(kH / T_{60}) - 0.15] / \alpha_1\} \qquad \text{(C.2)}$$

where k is the constant employed in Equation (1).

As shown in Table C.1, for either of the two maximum reverberation times, the required minimum surface area of acoustical treatment increases as the ceiling height increases and as the sound absorption coefficient decreases. The table shows the need to apply acoustical treatment to the walls as well as the ceiling for rooms with high ceilings and low sound absorption coefficients. Two examples illustrate application of the data in the table.

Example 1. A rectangular core learning space has dimensions of 40 ft long by 25 ft wide by 9 ft high. It is planned to install sound-absorbing material only on the ceiling. The enclosed volume is $(40 \times 25 \times 9) = 9000\ \text{ft}^3$. From Table 1, for this enclosed volume, the maximum reverberation time is 0.6 s at each of the three specified frequencies. Manufacturer's data indicate that the proposed acoustical ceiling material has sound absorption coefficients of 0.65, 0.80, and 0.90 at 500 Hz, 1000 Hz, and 2000 Hz, respectively.

From Table C.1, for the smallest absorption coefficient of 0.65 and the 9-ft ceiling height, the required minimum area of treatment is 90% of the floor area of $40 \times 25 = 1000\ \text{ft}^2$, or $900\ \text{ft}^2$. This leaves not more than 10% of the ceiling area free for lighting and other services. If the allowance for lighting area is inadequate, some acoustical treatment may have to be installed on the walls.

NOTE While the required sound absorption should be confirmed at each of the three frequencies, it will generally be found that conformance to the reverberation-time requirement of Table 1 at 500 Hz will also ensure conformance at the two higher frequencies.

If the manufacturer's sound absorption data are between the sound absorption coefficients listed in the first column of Table C.1, the required treatment area can be computed by interpolation in the Table. For example, if the lowest sound absorption coefficient for example 1 were 0.67 instead 0.65, the relative treatment area for the ceiling would be $90\% \times (0.65/0.67)$ or 87% of the floor area, or $870\ \text{ft}^2$, instead of $900\ \text{ft}^2$.

Table C.1 — Minimum surface area of acoustical treatment for different sound absorption coefficients, ceiling heights, and reverberation times

(a) Reverberation time, T_{60}, of 0.6 s

Sound absorption coefficient, α_1	Ceiling height, H, ft								
	8	9	10	11	12	13	14	15	16
	Ceiling height, H, m								
	2.44	2.74	3.05	3.35	3.66	3.96	4.27	4.57	4.88
	Minimum area of sound-absorbing material as a percentage of the floor area								
0.45	112	130	148	167	185	203	221	239	257
0.50	101	117	134	150	166	183	199	215	232
0.55	92	107	121	136	151	166	181	196	211
0.60	84	98	111	125	139	152	166	179	193
0.65	78	90	103	115	128	141	153	166	178
0.70	72	84	95	107	119	130	142	154	166
0.75	67	78	89	100	111	122	133	144	154
0.80	63	73	83	94	104	114	124	135	145
0.85	59	69	79	88	98	107	117	127	136
0.90	56	65	74	83	92	101	111	120	129
0.95	53	62	70	79	88	98	105	113	116
1.00	50	59	67	75	83	91	100	108	116
NOTE Sound absorption coefficients stated by a manufacturer to be greater than 1.0 based on laboratory tests may be taken as equal to 1.00 for purposes of this annex.									

(b) Reverberation time, T_{60}, of 0.7 s

Sound absorption coefficient, α_1	Ceiling height, H, ft								
	8	9	10	11	12	13	14	15	16
	Ceiling height, H, m								
	2.44	2.74	3.05	3.35	3.66	3.96	4.27	4.57	4.88
	Minimum area of sound-absorbing material as a percentage of the floor area								
0.45	91	107	122	138	154	169	185	200	216
0.50	82	96	110	124	138	152	166	180	194
0.55	75	87	100	113	126	138	151	164	177
0.60	68	80	92	104	115	127	139	150	162
0.65	63	74	85	96	106	117	128	139	149
0.70	59	69	79	89	99	109	119	129	139
0.75	55	64	73	83	92	102	111	120	130
0.80	51	60	69	78	86	95	104	113	121
0.85	48	57	65	73	81	90	98	106	114
0.90	46	53	61	69	77	85	92	100	108
0.95	43	51	58	65	73	80	88	95	102
1.00	41	48	55	62	69	76	83	90	97
NOTE Sound absorption coefficients stated by a manufacturer to be greater than 1.0 based on laboratory tests may be taken as equal to 1.00 for purposes of this annex.									

NOTE A similar table can be constructed from Equation (C.2) for a carpeted floor by changing the default value for A_R/S_f from 0.15 for uncarpeted floors to 0.2 for carpeted floors.

Example 2. For the same core learning space as in example 1, it is now considered necessary to improve the intelligibility of speech in this lecture-type classroom. In accordance with the guidance in C.3.1, additional sound-absorbing material is to be installed as a ring around the walls near the ceiling.

The sound-absorbing ceiling treatment is to be of the same material as for example 1, but the proposed acoustical wall treatment has manufacturer-stated absorption coefficients of 0.45, 0.60, and 0.70 at 500 Hz, 1000 Hz, and 2000 Hz, respectively.

In this case, as a working assumption, assume that the ceiling is to provide 60% of the total sound absorption while the remaining 40% of the total sound absorption is provided by the wall treatment.

Therefore, the ceiling treatment area should be 60% of the 900 ft^2 determined for example 1 or $0.6 \times 900 = 540$ ft^2. According to Table C.1, for the 9-ft ceiling and the smallest sound absorption coefficient of 0.45 for the wall treatment, the minimum required surface area of wall-treatment material would be 130% of the floor area of 1000 ft^2 if it were the only material used. However under the assumptions, only 40% of that area is required or $0.4 \times 1.3 \times 1000 = 520$ ft^2. For the room perimeter of 130 ft, the height of the wall treatment would need to be 4 ft on each of the four walls or 44% of the total wall area.

In summary, 540 ft^2 of ceiling treatment material and 520 ft^2 of wall treatment material would be required for the core learning space to conform to the 0.6-s reverberation time limit in Table 1 while providing good intelligibility of spoken words. Other distributions of ceiling and wall treatment areas could be evaluated if it were considered that too much of the available wall area was devoted to sound-absorbing material.

C.2.1 Sound absorption coefficients and related design considerations

The sound absorption coefficients for all acoustical materials supplied for the project should be determined in accordance with ASTM C423 [C2]. The learning facility owner's representative should request from the acoustical materials contractor(s): a) appropriate certification that all material(s) have been tested in full accordance with ASTM C423, and b) a table of the laboratory-certified sound absorption coefficients at 500, 1000 and 2000 Hz for the materials employed. The mounting condition employed for these tests should be identified and, preferably, should be the same as the as-installed mounting configuration. The designer should recognize that when the cavity depth behind the acoustical material in a laboratory configuration mounting is greater than that for the as-installed depth, the installed low-frequency sound absorption coefficients are usually less than those for the laboratory tests.

Tradeoffs between the sound absorption coefficients and the surface areas of treatment are allowed if the tradeoffs result in the same or lower reverberation times than those specified in Table 1 for each of the three frequencies.

When selecting acoustical materials to conform to the reverberation time criteria in Table 1, it is prudent to allow for sufficient surface area coverage using sound absorption coefficients that fall in the lower range of the coefficients that alternative suppliers may provide. This procedure helps insure that the properly certified material from the lowest-price bidder is adequate.

C.3 Further design guidance

C.3.1 Location of the absorbing material

In cases where there is no fixed lecture position for the teacher, and when ceiling heights are less than about 3 m (10 ft), the best design option is to place most if not all of the sound-absorbing material on the ceiling. For ceiling heights greater than 3 m (10 ft), which is discouraged for classrooms, an increasing amount of the sound-absorbing material will have to be placed on the walls as the wall height increases above 3 m. If nearly all of the installed sound-absorbing material is on the ceiling, then it is prudent to introduce furnishings such as bookshelves of adequate height to assure that sound waves traveling across the room are scattered in the direction of the sound-absorbing acoustical ceiling.

C.3.2 Mounting of acoustical treatment in classrooms

Ceiling acoustical treatment is normally suspended from the ceiling with an air space specified by the architect. The height of the airspace may, or may not, be the same as the 40 cm (16 inch) airspace commonly used by manufacturers to achieve the sound absorption coefficients that are measured by a testing laboratory. As long as the minimum airspace required for installing a lay-in ceiling exists, the actual sound absorption coefficient at frequencies of 500 Hz and higher should be not less than the published values. Experienced professionals should be consulted when reverberation at frequencies less than 500 Hz is a major concern. Wall-mounted materials should be installed, as recommended by the manufacturer, with clips or glue to the wall surface or be fastened to added spacers to achieve the stated sound absorption coefficients.

C.3.3 Carpeting in classrooms

Carpeting in a classroom (for example, in an area where young children sit on the floor together for a story) can help substantially to reduce the level of background noise in the classroom from chair and foot impacts or scuffling. Carpeting can also attenuate the transmission of this impact noise to the room below. The alternative use of neoprene chair leg tips should be considered as a way to help minimize chair-shuffling noise without the use of carpeting.

Carpeting alone usually does not provide enough sound absorption for classrooms since it is generally poor at low frequencies, even when newly installed. (See text following Equation (C.2) for further guidance.)

C.3.4 Absorption of furnishings and occupants

Calculations of reverberation times for learning spaces assume typical furnishings such as chairs, desks, tables, and storage cabinets. A sound absorption equal to 5% of the floor area, already included in the residual absorption term A_R in Equation (C.2), is a conservative approximation for the sound absorption of these furnishings. These furnishings are normally floor-mounted and thus their quantity and hence their sound absorption will tend to be proportional to the floor area. The 5% figure is consistent with limited experimental data comparing the reverberation for furnished and unfurnished classrooms.

The sound absorption of learning-space occupants was considered in setting the limits on reverberation time in Table 1 and should not be included again in any calculations for the reverberation time of an unoccupied space. The sound absorption provided by an occupant is approximately equal to 0.55 m^2 (6.0 ft^2) for an adult student and about 20% less for a high school student and 40% less for an elementary grade student [C4].

C.4 Guidelines for good acoustical characteristics in large classrooms and lecture rooms

This standard does not specify performance criteria or design requirements for enclosed learning spaces with enclosed volumes larger than 566 m^3 (20 000 ft^3). However, limited additional recommendations and design guidelines for larger rooms and other spaces in educational facilities, aside from those in C.3.1 and C.3.2, are given in this subclause.

Large lecture rooms generally differ physically and functionally in many ways from classrooms found in elementary and secondary schools. The teacher-student configuration tends to be fixed; the size of the room can vary greatly, sometimes accommodating hundreds of students; the shape of the room may vary from a traditional rectangular shape; HVAC systems usually have much greater capacities; and speech reinforcement systems as well as other fixed audiovisual facilities are common in such spaces.

For unamplified speech, beneficial sound-reflecting surfaces, especially over the teacher-lecturer, are necessary to assure adequate speech sound levels in the back of the room with relatively uniform distribution of the sound of spoken words. If the teacher-student configuration is fixed, beneficial reflections can be obtained with sound-reflecting surfaces placed above the lecturer, sometimes extending over the audience, on the ceiling, or sidewalls. Because of the larger room volumes, reverberation times usually are greater than in small classrooms, with values of 0.7 s to 1.1 s in occupied rooms not uncommon. To assure less variability in the reverberation time with changes in occupancy, it is always desirable to have sound-absorbing upholstered chairs in small auditoria. To minimize echoes, the back wall of the room is often made sound absorbing, or is tilted to avoid sending reflections back toward the source, or both.

Because of the complexity of the design of large lecture rooms, experienced professionals should be consulted to ensure that the design and its implementation achieve the acoustical objectives of this standard.

Further guidance for detailed design considerations of lecture rooms can be found in a number of sources including [C1, C4-C11] listed in the bibliography to this annex.

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