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Designation: E 1111 – 02

Standard Test Method for Measuring the Interzone Attenuation of Ceiling Systems[1]

This standard is issued under the fixed designation E 1111; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—Keywords were added editorially in September 1996.

INTRODUCTION

This test method is one of a series for the measurement and evaluation of acoustical parameters affecting speech privacy in open-plan spaces. The maximum privacy theoretically available at normal working distances in open-plan spaces, with partial height space dividers (screens), is insufficient to cope with normal speech without the assistance of relatively elevated background masking sound levels. Thus, the provision of adequate speech privacy in open-plan offices and schools is one of the most difficult tasks in the architectural acoustics field. This test method provides a means of objectively measuring the relevant acoustical characteristics of one component in the open-plan space, the ceiling system.

[1] This test method is under the jurisdiction of ASTM Committee E-33 on Environmental Acoustics and is the direct responsibility of Subcommittee E33.02 on Open Plan Spaces.

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1. Scope

1.1 This test method[2] is intended to provide measurements of the sound reflective characteristics of ceiling systems when used in conjunction with partial-height space dividers. This arrangement is commonly used in offices and schools to achieve speech privacy between work zones in the absence of full-height partitions. This test method is applicable to any ceiling configuration, including, for example, a pattern of sound-reflective panels in an otherwise sound-absorptive ceiling. This test method, as specified, is primarily restricted to measurements with a fixed space divider height of 1.50 m (60 in.), a ceiling height of nominally 2.70 m (108 in.), a source height of 1.20 m (48 in.), and microphone positions at 1.20 m (48 in.) height. In recognition of trends toward alternate divider heights in open office environments, measurements with an alternate divider height may be conducted in accordance with this standard.

1.2 *Laboratory Accreditation*—A procedure for accrediting a laboratory for purposes of this test method is given in Annex A1.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are provided for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

C 423 Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method[3]

C 634 Terminology Relating to Environmental Acoustics[3]

E 1110 Classification for Determination of Articulation Class[3]

E 1179 Specification for Sound Sources Used for Testing Open Office Components and Systems[3]

2.2 *ANSI Standards:*

[2] This test method is similar to a procedure developed by the U.S. Government General Services Administration, Public Buildings Service, designated 'PBS-C.2, Test Method for the Sufficient Verification of Speech-Privacy Potential Based on Objective Measurements including Methods for the Rating of Functional Interzone Attenuation and NC-Background.' August 1972.

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

S1.6 Preferred Frequencies and Band Numbers for Acoustical Measurements[4]
S1.11 Specification for Octave Band and Fractional-Octave-Band Analog and Digital Filters[4]
S1.12 Specification for Laboratory Standard Microphones[4]

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 ~~*interzone attenuation*~~*nominal reference level*~~—at—~~for a ~~specified position, for a~~ one-third octave-band, the ~~difference between the~~ arithmetic mean of sound pressure levels measured between the ~~nominal reference position 0.9 m (3 ft) from the sound~~ source point and the ~~sound pressure level~~ space divider at ~~the point in question.~~ specified positions.

3.1.2 *interzone attenuation*—at a specified position, for a one-third octave band, the difference between the nominal reference level and the sound pressure level at the point in question.

3.1.3 *nominal interzone attenuation*—for a one-third octave-band, at a specified point, the arithmetic mean interzone attenuation calculated using the interzone attenuation for the point in question and for two adjacent positions 0.3 m (1 ft) to either ~~side. For example, the nominal interzone attenuation at the 3.0-m (10-ft) position is the arithmetic mean of the interzone attenuations at the 2.7, 3.0 and 3.3-m (9, 10, and 11-ft) positions.~~ side.

4. Summary of Test Method

4.1 The test facility (Fig. 1) is essentially an expanse of floor and ceiling in which all vertical surfaces have negligible sound reflections. The facility may be set up in a laboratory, in a mock-up of a proposed building, or in a completed building. The standard space divider is of such dimensions and construction that sound generated on one side can reach a measuring point on the other side only by way of diffraction over the top of the space divider and by reflection from the ceiling. With the diffracted component fixed by the dimensions of the space divider and by the height of the source and measurement position, the difference between the sound levels measured on each side of the space divider provides a comparative measure of the contribution of ceiling system reflection to the total sound transmission.

4.2 When the test is conducted in a mock-up of a proposed building or in a completed building, strict adherence to the test method may not be possible in that the conditions of ceiling height and plenum depth, etc., cannot be met because of the building design. Under these circumstances, the measurements apply only to that situation and other identical situations.

5. Significance and Use

5.1 The substitution of moveable part-height space dividers for fixed full-height partitions between work zones in open-plan offices and schools may introduce problems of inadequate speech privacy or distraction between zones. A space divider placed between zones serves as a partial sound barrier, but its effectiveness can be compromised by ~~d~~ reflection of sound over the space

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

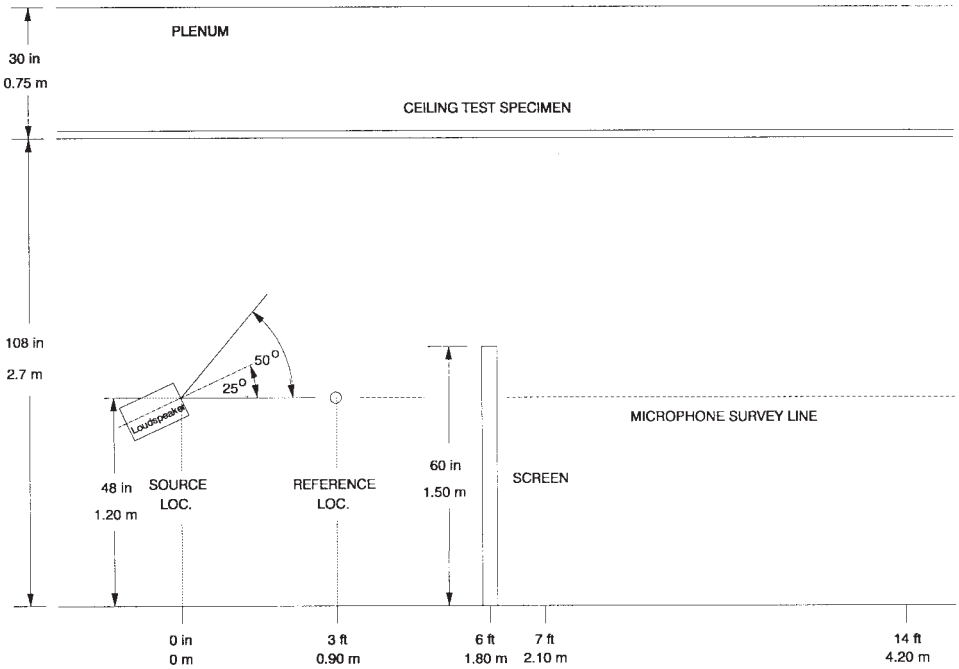

FIG. 1 Ceiling Test Facility

divider by the ceiling. An evaluation of the sound reflective characteristics of a ceiling system may therefore serve as a useful design tool in providing the speech privacy required in a given open-plan layout. Although the potential speech privacy may be limited by other components of the open-plan space, this document is concerned only with ceiling system performance in association with a specified space divider construction.

5.2 The provision of speech privacy in open-plan spaces is dependent upon many factors, the most significant of which are the following: *(1)* the *shadow* zone of part-height space dividers and the diffraction of sound from the edges of space dividers; *(2)* the primary sound reflective properties of the ceiling system; *(3)* the level of masking sound present in the space; and *(4)* the distance between speaker and listener.

NOTE 1—The first factor is standardized in this test method and the third is eliminated. Experience has indicated that results obtained by this test method may not fairly represent the speech privacy that may be achievable with nonflat ceiling systems.

5.3 The significance of test results obtained by this test method must also be considered with regard to the attainable measurement accuracy. The attainment of speech privacy in the presence of masking noise is critically dependent upon sound level of the speech relative to the masking sound; a change as small as 2 dB in either the speech or masking sound may change the privacy from significant to insignificant perceived speech intelligibility. The normally accepted test accuracies for sound attenuation measurements may be inadequate to evaluate ceiling systems having marginal interzone attenuation performance for open-plan space needs.

6. Laboratory Test Facility

6.1 The area of the facility shall be preferably at least 4.5 by 9 m (15 by 30 ft).

6.2 The floor shall be of a solid material such as concrete or plywood weighing at least 20 kg/m^2 (4 lb/ft^2). It shall be covered with carpet without underpad typical of those used in open plan spaces. The absorption coefficients of the carpet shall be measured in accordance with Test Method C 423, and the ~~noise reduction coefficient (NRC)~~ sound absorption average (SAA) shall lie in the range from ~~0.2~~ 0.15 to 0.4.

6.3 The walls shall have random incidence sound absorption coefficients of at least 0.9 for all test ~~frequencies.~~

~~6.3.1 The~~ frequencies. The wall covering sound absorption shall be measured in accordance with Test Method C 423 with a mounting equivalent to that used in the test facility.

6.4 The space divider ~~shall be 1.50 m (60 in.) high and~~ shall extend the full width of the facility between the side walls and shall be placed at least 2.70 m (108 in.) from both end walls. It shall have a core of rigid, impermeable material weighing not less than 7.0 kg/m^2(1.4 lb/ft^2), and shall be faced on both sides with a 50 mm (2.0 in.) thickness of sound absorbing material. The core shall extend fully to the top of the space divider, as shall the sound absorption facing material. The space divider shall have a minimum ~~NRC~~ SAA of 0.80 when measured in general accordance with the provisions for testing office space dividers in Test Method C 423. There shall be no gap between the bottom of the space divider and the floor. If the space divider is assembled in sections, care shall be taken to minimize sound transmission at the joints. Measurements shall be made with a space divider 1.5 m (60 in.) high. Measurements may also be made with a space divider 1.8 m (72 in.) high.

NOTE 2—Because the core and absorptive facings of the divider extend to its top, the divider may not be capped.

7. Field Test Facility

7.1 For tests in a field prototype or completed building, the same degree of suppression of horizontal reflections shall be achieved as for the laboratory facility. This may be effected either by enclosing the test area temporarily with highly absorptive panels, by covering nearby reflective vertical surfaces with such materials, or by choosing a test site that is far removed from any reflective vertical surfaces.

7.2 The space divider shall be at least 4.5 m (15 ft) wide and of substantially the same construction as for the laboratory facility.

8. Apparatus

8.1 *Loudspeaker,* enclosed in a small box, driven by broadband or random noise. The loudspeaker shall meet the specifications and requirements of Specification E 1179.

8.1.1 The generated sound power shall be adequate to maintain one-third octave band sound pressure levels of at least 10 dB above the ambient noise levels of the test facility and the internal noise levels of the measuring instrumentation at each of the desired measurement locations.

8.2 *Microphone*—The microphone shall meet the requirements of ANSI S1.12 and shall have a free field correction of not more than 2 dB for sound waves at all measurement frequencies incident on the microphone diaphragm from 30 to ~~90°. The microphone shall be mounted vertically with the diaphragm pointing upwards.~~ 90°.

8.3 *Filters*—Filters used with the microphone or source amplifiers shall conform to ANSI Specification S 1.11 for Order 3, Type 1, ⅓ octave-band filters.

9. Sampling

9.1 A ceiling system constructed as a specimen for this test method will be a complex assembly of many component parts. Therefore, a requirement for minimum sampling is impractical and not required. However, the individual components shall be randomly selected from normal stock.

10. Test Specimen

10.1 The ceiling to be tested shall cover the entire area of the laboratory facility, or at least a 4.5 by 9 m (15 by 30 ft) area in a field test facility. Its nominal level shall be 2.75 m ± 50 mm (9 ft ± 2 in.) above the floor, and it shall be suspended from a flat structural slab or deck with a plenum depth of not less than 0.60 m (24 in.) with a preferred depth of 0.75 m (30 in.). The upper and perimeter surfaces of the plenum shall be sound reflective. The plenum shall contain no ducts, beams, or similar obstructions that will affect the test results. The nominal ceiling level shall be defined as that of the exposed surface of a continuous flat ceiling, or of the lowest exposed surface of a nonflat ceiling. If, in a field test situation, the ceiling height and plenum conditions cannot be met, this test method may be used to evaluate the test setup and may not be used to obtain general interzone attenuation data for the ceiling system.

10.2 When the ceiling assembly includes differing elements in the horizontal plane, such as light fixtures or varying ceiling levels, the orientation with respect to the space divider and the sound measurement survey line shall be described and reported.

NOTE ~~23~~—In a ceiling containing both sound absorptive and reflective areas such as light fixtures, interzone attenuation values may ~~vary~~ differ widely depending on the location of the survey line with respect to the ceiling layout. It is therefore advantageous to choose two or three survey lines in such a way as to yield both maximum and minimum attenuations. The orientation and survey line for minimum attenuation shall always be measured and reported.

11. Procedure

11.1 Place the sound source in a position above the floor, facing the space divider and pointed upward at an angle of 25° to the floor, so that the lower plane of a 50° included angle meeting the directional requirements of Specification E 1179 is parallel to the floor. Position the point where the loudspeaker axis intersects the front plane of the loudspeaker enclosure 1.20 m (48 in.) above the floor at a distance of 1.80 m (72 in.) from the center of the space divider (Fig. 1).

11.2 The sound signal ~~should~~ shall be pink or white noise ~~with a continuous frequency spectrum within each of the one-third octave bands~~ in the range from 200 to 5000 Hz center frequencies, as defined in ANSI S1.6. If desired, the range may be extended provided that the requirements of Specification E 1179 are ~~met. Either pink noise or white noise as defined in Terminology C 634 is satisfactory for this test method.~~

~~11.3 Take~~ met.

11.3 The precision associated with the measurement of sound pressure levels depends on the interpretation of the output of the instrumentation that might be a sound level meter, le~~a~~vel recorder, or di~~n~~gital analyzer. In any event, levels should be measured with an uncertainty of less than 0.5 dB with 95 % confidence.

11.4 The bias of level measurements and differences is determined by the bias of all the associated instrumentation. Any inaccuracies in this area should be made negligible by careful calibration.

11.5 The measurement of nominal interzone attenuation for each test frequency shall have an uncertainty of 1 dB or less with 95 % confidence.

11.6 Each microphone ~~placed~~ shall be calibrated at regular intervals and a record shall be kept of the dates of such calibration. If multiple microphones are used, their adjusted sensitivities shall be matched within 0.5 dB in each of the specified frequency bands. Calibration over the whole range of test frequencies shall be done annually, and calibration checks for at least one frequency shall be made prior to each test.

11.7 Measurements shall be made to ensure that variation of the sound source does not effect the test. This can be repeated measurements at a reference position made at the beginning and end of the test, or simultaneous measurement of the nominal reference level and other measurement points. Variations should not exceed 0.5 dB in any frequency band.

11.8 Measurements shall be taken along a survey line extending 1.20 m (48 in.) ~~above~~ from the floor and extending from the ~~intersection of~~ point where the loudspeaker axis ~~and~~ intersects the loudspeaker enclosure front plane through and perpendicular to the space divider.

~~11.4 Orient the~~

11.9 The microphone ~~as specified in 8.2.~~

~~11.5 Obtain~~ shall be mounted vertically with the ~~reference level in each one-third octave band by conducting measurements on~~ diaphragm pointing upwards.

11.10 Obtain the ~~survey line~~ nominal reference level, measured at ~~0.60 m, 0.90 m,~~ 0.6, 0.9 and 1.2~~0~~ m, (2, 3, and 4 ft.), from the source ~~point. The reference level at~~ point along the ~~0.90-m reference position (Fig. 1) is the arithmetic mean sound pressure level of the three measurement points. Additional measurements may be taken at points equi-spaced about the 0.90-m position, but not beyond the 0.60-m or 1.20-m positions, and included~~ survey line specified in ~~the measured reference level.~~

~~11.6 Make~~ 11.8 for each one-third octave band.

11.11 Make measurements on the receiving side of the space divider (facing away from the source point) at 0.30-m (12-in.) intervals along the survey line specified in 11.~~3~~8. The nearest position shall be 2.1 m (7 ft) from the source and the farthest position 4.20 m (14 ft) from the source. Additional measurements may be made at greater or smaller distances, as desired.

11.~~7~~12 Determine the interzone attenuation for each one-third octave-band at each receiving position by calculating the difference, ~~rounded to the nearest decibel,~~ between the nominal reference ~~sound pressure level~~ level, measured according to Section 11.10, and the level measured at the receiving ~~position. The interzone attenuation is the difference in decibels between the~~ position,

measured ~~reference level and~~ according to Section 11.11.

11.13 Calculate the ~~measured level at the receiving position.~~

~~11.8 Calculate the~~ nominal interzone ~~attenuation as specified in 3.1.1~~ attenuation, for each of the 2.4, 2.7, 3.0, 3.3, 3.6 and 3.9-m (8, 9, 10, 11, 12 and 13-ft) positions. For example, the nominal interzone attenuation at the 3.0-m (10 ft) position is the arithmetic mean of the interzone attenuations at the 2.7, 3.0, and 3.3-m, (9, 10, and 11 ft) positions.

12. Single Number Classification

12.1 The articulation class (AC) shall be calculated in accordance with Classification E 1110 ~~for each~~ using the nominal interzone attenuations for each distance specified in 11.13.

12.2 The minimum articulation class is the minimum AC measured for a given spałce divider height.

12.3 The articulation class reported for a space divider 1.5 m (60 in.) high shall be designated AC(1.5). The articulation class reported for a space divider 1.8 m (72 in.) high shall be designated AC(1.8). Articulation class measurements reported for other height dividers shall be designated AC followed by the height of the ~~nominal interzone distances, with~~ space divider in meters rounded to the ~~positions clearly identified. The~~ nearest 0.1 meters within parenthesis. Similarly, the minimum ~~of these AC values may~~ articulation class shall be reported ~~as~~ with the ~~*minimum articulation class*~~, height of the divider within parenthesis, i.e. AC(1.5) min.

NOTE 4—The designation AC without a ~~qualifying distance or location.~~ height in parentheses was used in previous editions of this method and implies a space divider 1.5 m, (60 in), high.

13. Report

13.1 Report the following information:

13.1.1 A statement, if correct in every respect, that the test has been conducted in full accordance with this test method,

13.1.2 A full description of deviations, if any, from this test method,

13.1.3 A complete description of the ceiling materials, components, method of assembly, and configuration,

13.1.4 A description and drawing of the position and orientation of the survey line and space divider with respect to the horizontal configuration of the ceiling, and

13.1.5 For each space divider height measured, with the height of the space divider clearly identified:

13.1.5.1 A tabulation or chart, or both, of interzone attenuation ~~values~~ rounded to the nearest tenth dB at all measurement positions and all one-third octave bands for the minimum center frequency range from 200 to 5000 Hz.

13.1.5.2 A tabulation or chart, or both, of nominal interzone attenuation rounded to the nearest tenth dB at all nominal measurement positions and all one-third octave bands for the minimum center frequency range from 200 to 5000 Hz.

13.1.5.3 The articulation class for each nominal interzone distance.

13.1.5.4 The minimum of these articulation class values reported as the *minimum articulation class* with the height of the space divider following in parentheses, without a qualifying distance or location.

14. Precision and Bias

14.1 The precision ~~associated with the measurement~~ of ~~sound pressure levels depends on~~ the ~~interpretation of the output of the instrumentation that might be a sound level meter, level recorder, or digital analyzer. In any event, levels should be measured with an uncertainty of less than 0.5 dB with 95 % confidence.~~

~~14.2 The bias of level measurements and differences is determined by the bias of all the associated instrumentation. Any inaccuracies in this area should be made negligible by careful calibration.~~

~~14.3 The precision of the~~ test method should be obtained ~~annually~~ in each laboratory by performing several tests on a single specimen. ~~The test specimen~~ This should be ~~removed and reinstalled in the test facility after each test~~ repeated if changes are made to ~~obtain~~ the ~~measured repeatability.~~

~~14.4 Within a single laboratory the mean value for each test frequency should have an uncertainty of 1 dB or less with 90 % confidence. Changes in procedure or~~ instrumentation ~~may be necessary to achieve this figure.~~

~~14.5 A~~ or the measurement process.

14.2 A comparison between five laboratories[5] with three ceiling products ranging from highly sound reflective to highly sound absorptive showed uncertainties with 90 % confidence as follows:

14.52.1 In the one-third octave frequency range from 500 to 3150 Hz, the uncertainties were within ±1.5 dB.

14.52.2 In the range from 200 to 400 Hz, the uncertainties were within ±2.8 dB.

14.52.3 In the range from 4000 to 5000 Hz, the uncertainties were within ±1.8 dB.

15. Keywords

15.1 acoustical; ceiling systems; interzone attenuation; open-plan

[5] Supporting data are available from ASTM Headquarters. Request RR: E33 – 1002.

ANNEX

(Mandatory Information)

A1. LABORATORY ACCREDITATION

A1.1 Scope

A1.1.1 This annex provides guidelines for agencies evaluating testing laboratories for the purpose of granting accreditation for Test Method E 1111.

A1.2 Referenced Documents

A1.2.1 *ASTM Standards*:
C 634 Terminology Relating to Environmental Acoustics[3]
E 548 Standard Guide for General Criteria Used for Evaluating Laboratory Competence[6]
E 717 Guide for the Preparation of the Accreditation Annex of Acoustical Test Standards[3]

A1.3 Terminology

A1.3.1 The acoustical terminology used in this annex is consistent with Terminology C 634 and ~~Practice~~ Guide E 548.

A1.4 ~~Organization of~~General Requirements

A1.4.1 The testing agency will make available to the ~~Agency~~
~~A1.4.1 A description of~~ accrediting authority the ~~organization shall be given following the requirements~~ information required by Sections 4–7 of ~~Practice~~ Guide E 548.

A1.5 ~~Human Resources of the Agency~~

~~A1.5.1 A description of the agency personnel responsible for testing should be supplied following the requirements of Practice E 548.~~

~~A1.6~~ Field Testing

A1.6~~5~~.1 Accreditation shall not be given for field tests as described in 7.1 of this test method.

~~A1.7 Facility Requirements~~

~~A1.7.1 The laboratory~~

A1.6 Requirements Specific to This Method

A1.6.1 *Physical Facilities*—The testing agency shall provide information demonstrate~~ing~~ compliance with the ~~requirements~~ following provisions of ~~6.1, 6.2, 6.3.1, and 6.4. Test data shall be produced where appropriate.~~

~~A1.8 Apparatus~~

~~A1.8.1 The laboratory shall have evidence that the apparatus used meets the requirements of 8.1.1, 8.2, 8.3, and Specification E 1179.~~

~~A1.9 Test Specimen~~

~~A1.9.1 The laboratory~~ this test method:

Test Facility	6
Apparatus	7
Test Specimen	8

A1.6.2 *Procedures*—The testing agency shall ~~install the~~ provide a sample report of a complete test ~~specimens in accordance~~ (including raw data), showing compliance with the ~~requirements~~ following provisions of ~~10.1 and in accordance with the specifications of the manufacturer(s) of the~~ this test ~~specimens.~~

~~A1.10 Source Position~~

~~A1.10.1 The laboratory shall~~ method:

Test Signal	11.2

[6] *Annual Book of ASTM Standards*, Vol 14.02.

~~Speaker position the sound source as specified in 11.2~~	~~11.1~~

~~A1.11 Standard Test Frequencies~~

~~A1.11.1 The laboratory shall conduct the measurements at the frequencies specified in 11.2.~~

~~A1.12 Measurements~~

~~A1.12.1 The laboratory shall take measurement readings at the microphone orientation and positions specified in 11.3~~

~~A1.12.2 The laboratory shall measure the~~

Speaker position	11.1
Survey line	11.8
Calibration	11.6
Signal stability	11.7
~~Nominal reference and receiving sound pressure level~~	~~11.10~~
Nominal reference level	11.10
~~Receiving levels as defined in 11.5 and 11.6.~~	~~11.11~~

~~A1.12.3 The laboratory shall calculate the interzone~~

Receiving levels	11.11
~~Interzone attenuation and nominal~~	~~11.12~~
Interzone attenuation	11.12
~~Nominal interzone attenuations as defined in 11.7 and 11.8.~~	~~11.13~~

~~A1.13 Reporting Data~~

~~A1.13.1 The laboratory shall adhere to all the requirements of Section 13 for reporting interzone attenuation.~~

~~A1.14 Precision and Bias~~

~~A1.14.1 Data shall be presented to demonstrate that the measurement attenuation~~

Nominal interzone attenuation	11.13
Articulation class	12.1
Report contents	13
Repeatability	14.1

meets the requirements of 14.1 and 14.1.1.

A1.14.2 Calibration records shall be produced to demonstrate compliance with 14.2.

A1.15 General

A1.15.1 Instruments, techniques, and individual capabilities may vary between testing laboratories. The accrediting agency shall ensure that its accrediting personnel are competent to deal with and evaluate correctly unusual test conditions, instruments, or techniques.