INTERNATIONAL

Designation:E492–04 Designation: E 492 – 09

Standard Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine[1]

This standard is issued under the fixed designation E 492; 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.

INTRODUCTION

This test method is one of several for evaluating the sound insulating properties of building elements. It is designed to measure the impact sound transmission performance of an isolated floor-ceiling assembly, in a controlled laboratory environment. Others in the set deal with field measurement of impact sound transmission through floor-ceiling assemblies, and the laboratory and field methods of measuring airborne sound transmission loss of building partitions such as walls, floor-ceiling assemblies, doors, and other space-dividing elements.

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1. Scope

1.1 This test method covers the laboratory measurement of impact sound transmission of floor-ceiling assemblies using a standardized tapping machine. It is assumed that the test specimen constitutes the primary sound transmission path into a receiving room located directly below and that a good approximation to a diffuse sound field exists in this room.

1.2 Measurements may be conducted on floor-ceiling assemblies of all kinds, including those with floating-floor or suspended ceiling elements, or both, and floor-ceiling assemblies surfaced with any type of floor-surfacing or floor-covering materials.

1.3 This test method prescribes a uniform procedure for reporting laboratory test data, that is, the normalized one-third octave band sound pressure levels transmitted by the floor-ceiling assembly due to the tapping machine.

1.4 *Laboratory Accreditation*—The requirements for accrediting a laboratory for performing this test method are given in Annex A2.

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

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

2. Referenced Documents

2.1 *ASTM Standards:* *ASTM Standards:*[2]

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

C 634 Terminology Relating to Environmental Acoustics

E90Terminology Relating to Building and Environmental Acoustics

[1] This test method is under the jurisdiction of ASTM Committee E33 on Building and Environmental Acoustics and is the direct responsibility of Subcommittee E33.03 on Sound Transmission.

Current edition approved April 1, 2004. Published May 2004. Originally approved 1973. Last previous edition approved 1996 as E492–90 (1996)$^{\varepsilon 1}$.

Current edition approved April 1, 2009. Published May 2009. Originally approved in 1973. Last previous edition approved in 2004 as E 492 – 04.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

E 90 Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements
E548Guide for General Criteria Used for Evaluating Laboratory Competence
E717Guide for the Preparation of the Accreditation Annex of Acoustical Test Standards
336 Test Method for Measurement of Airborne Sound Attenuation between Rooms in Buildings
E 989 Classification for Determination of Impact Insulation Class (IIC)
E 1007 Test Method for Field Measurement of Tapping Machine Impact Sound Transmission Through Floor-Ceiling Assemblies and Associated Support Structures
E 1414 Test Method for Airborne Sound Attenuation Between Rooms Sharing a Common Ceiling Plenum
E 2235 Test Method for the Determination of Decay Rates for Use in Sound Insulation Test Methods

2.2 *ANSI Standards:*[3]

S1.10 Pressure Calibration of Laboratory Standard Pressure Microphones
S1.11 Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters S1.26Method for the Calculation of the Absorption of Sound by the Atmosphere[4]

2.3 *ISO Standard:*

S1.43 Specification for Integrating-Averaging Sound-Level Meters
S12.51 Acoustics—Determination of Sound Power Levels of Noise Sources Using Sound Pressure—Precision Methods for Reverberation Rooms

2.3 *ISO Standards:*[3]

ISO 140/6Acoustics—Measurement of Sound Insulation in Buildings and of Building Elements Part 6: Laboratory Measurements of Impact Sound Insulation of Floors[4] Acoustics—Measurement of Sound Insulation in Buildings and of Building Elements Part 6: Laboratory Measurements of Impact Sound Insulation of Floors
ISO 3741 Determination of Sound Power Levels of Noise Sources Using Sound Pressure—Precision Methods for Reverberation Rooms

2.4 *IEC Standards:*[4]

IEC 60942 Electroacoustics—Sound Calibrators
IEC 61672 Electroacoustics—Sound Level Meters—Part 1: Specifications

3. Terminology

3.1The acoustical terminology used in this method is consistent with Terminology C634 except for the following special usages.

3.1 The following terms used in this test method have specific meanings that are defined in Terminology C 634:

airborne sound
average sound pressure level
background noise
decay rate
decibel
diffuse sound field
impact insulation class
one-third octave band
receiving room
reverberant sound field
reverberation room
sound absorption
sound pressure level

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *receiving room*—a reverberant room below the floor specimen under test in which the sound pressure levels due to the tapping machine are measured.

3.2.2*source room*—the room containing the tapping machine. —a reverberation room below the floor specimen under test in which the sound pressure levels due to the tapping machine are measured.

4. Summary of Test Method

4.1 A standard tapping machine is placed in operation on a test-floorfloor specimen that forms is intended to represent a horizontal separation between two rooms, one directly above the other. (See Section 6.) The transmitted impact sound characterized by the average spectrum of the space-time average one-third octave band sound pressure levels produced by the tapping machine is measured in the receiving room below in one-third octave bands.

4.2 Since the spectrum depends on the absorption of the receiving room, the sound pressure levels are normalized to a reference absorption for purposes of comparing results obtained in different receiving rooms that differ in absorption.

[3] Withdrawn
[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.
[4] Available from International Electrotechnical Commission (IEC), 3 rue de Varembé, Case postale 131, CH-1211, Geneva 20, Switzerland, http://www.iec.ch.

5. Significance and Use

5.1The evaluation of the impact sound-insulating performance of a floor-ceiling assembly begins with the measurement of the sound pressure levels in the room below the test specimen. The spectrum of the noise in the room below is determined by the following:

5.1 The spectrum of the noise in the room below the test specimen is determined by the following:

5.1.1 The size and the mechanical properties of the floor-ceiling assembly, such as its construction, surface, mounting or edge restraints, stiffness, or internal damping,

5.1.2The acoustical response of the room below, and

5.1.3Inevitably, the characteristics and placement of the object or device producing the impacts and the nature or degree of the actual impact itself.

5.2This test method is based on the use of a standardized tapping machine of the type specified in 8.1.1 and placed in specific positions on the floor. This machine produces a continuous series of uniform impacts at a uniform rate on a test floor and generates in the receiving room broadband sound pressure levels sufficiently high to make accurate and reproducible measurements possible. The tapping machine itself, however, is not designed to simulate any one type of impact, such as produced by male or female footsteps.

NOTE1—**Caution:**Because of its portable design, the tapping machine does not simulate the weight of a human walker. Therefore, the creak or boom of a limber floor assembly caused by such footstep excitation may not be reflected in the single number impact rating derived from test results obtained by this test method. The degree of correlation between the results of tapping machine tests in the laboratory and the overall field performance of floors under typical conditions of domestic impact excitation may be subject to some variation, depending on both the type of floor construction and the nature of the impact excitation.

6.

5.1.2 The acoustical response of the room below,

5.1.3 The placement of the object or device producing the impacts, and

5.1.4 The nature of the actual impact itself.

5.2 This test method is based on the use of a standardized tapping machine of the type specified in 8.1 placed in specific positions on the floor. This machine produces a continuous series of uniform impacts at a uniform rate on a test floor and generates in the receiving room broadband sound pressure levels that are sufficiently high to make measurements possible beneath most floor types even in the presence of background noise. The tapping machine itself, however, is not designed to simulate any one type of impact, such as produced by male or female footsteps.

5.3 Because of its portable design, the tapping machine does not simulate the weight of a human walker. Therefore, the structural sounds, i.e., creaks or booms of a floor assembly caused by such footstep excitation is not reflected in the single number impact rating derived from test results obtained by this test method. The degree of correlation between the results of tapping machine tests in the laboratory and the subjective acceptance of floors under typical conditions of domestic impact excitation is uncertain. The correlation will depend on both the type of floor construction and the nature of the impact excitation in the building.

5.4 In laboratories designed to satisfy the requirements of this test method, the intent is that only significant path for sound transmission between the rooms is through the test specimen. This is not generally the case in buildings where there are often many other paths for sounds— *flanking sound transmission*. Consequently sound ratings obtained using this test method do not relate directly to sound isolation in buildings; they represent an upper limit to what would be measured in a field test.

5.5 This test method is not intended for field tests. Field tests are performed according to Test Method E 1007.

6. Test Rooms

6.1*Flanking Transmission*:

6.1.1The test rooms shall be so constructed and arranged that the test specimen constitutes the only important transmission path between them. The impact sound pressure level transmitted through the test structure shall be at least 10 dB greater than that transmitted into the receiving room by all other paths.

6.1.2The limit of impact sound levels that can be measured in the receiving room without being biased by flanking transmission must be determined for each test facility. A suggested method is to build and install in the usual manner a test specimen and to measure the vibration acceleration levels of the test specimen in the receiving room and the receiving room walls. If the former exceeds the latter by 10 dB, one may consider the flanking transmission due to vibrating room surfaces as negligible. The amount of energy radiated from a structure depends upon its radiating efficiency as well as its amplitude of vibrations.

6.1 The test facility shall be so constructed and arranged that the test specimen constitutes the only important transmission path for the tapping machine sound.

NOTE2—The amount of flanking transmission may also be determined by using sound intensity techniques to measure the contribution of the radiating surfaces and any possible airborne leaks.

6.2*Size and Shape of Receiving Room*—To produce an acceptable approximation to the assumed diffuse sound fields, especially in the lowest test frequency band, the receiving room should meet the following requirements.

6.2.1 *1—Common methods for ensuring that this requirement is satisfied include mounting the specimen resiliently in the test opening, mounting the specimen in a resiliently supported test frame, and supporting rooms resiliently. In general, all rigid* connections between the specimen and the test rooms should be avoided.

6.2 The spatial variations of sound pressure level measured in the receiving room shall be such that the precision requirements in Annex A1 are satisfied at all frequencies.

6.3 *Volume of Receiving Room*—The recommended minimum volume of the receiving room is 125 m^3(4415 ft^3). Laboratories that use a volume smaller than 125 m^3 must report the room volume in their test report (**1, 2**).

6.2.2*Room Shape*—It is recommended that no two dimensions of the receiving room be the same or in the ratio of small whole numbers. The ratio of largest to smallest dimension of the room should be less than two. .

NOTE3—Theoretical studies of rectangular rooms (**2, 3, 4**) suggest that the proportions $1:2^{1/3}:2^{2/3}$ provide an optimum distribution of modes in the lowest bands. Minor deviations in construction, or the presence of diffusers, will alter the actual distribution.

6.3*Sound Diffusion*— Even in receiving rooms meeting the requirements of 6.2, measurements in the lower test bands are likely to depend critically on microphone locations. Space/time variations in measured sound pressure levels can be minimized by using a diffusing panel system that incorporates stationary or moving diffusing panels, or both. For this reason it is suggested that the receiving room should be fitted with diffusing panels. It has been found that diffusing panels meeting the following requirements have been effective in diffusing sound fields. This is not to say that other diffusing panels are more or less effective. Each laboratory should select and install diffusing elements such that they meet the precision requirements of 11.3.

6.3.1The recommended minimum dimension of any diffusing panel is 1 m excluding thickness and recommended minimum surface mass of the panels is 5 kg/m^2 (1 lb/ft^2).

6.3.2Fixed diffusing panels should be suspended in random orientations throughout the room space. The distribution of the panels should be determined experimentally in order to provide an acceptably uniform sound which satisfies the precision requirements of 11.3.

6.3.3Moving diffusers usually comprise a set of rotating or oscillating panels set at oblique angles relative to the room surfaces. These devices are known to be particularly effective in producing a uniform sound field.

6.3.4The recommended total single-sided area of fixed plus moving panels should be greater than 10 to 15% of the total surface of the receiving room. 2—See Test Method E 90 for recommendations for new construction.

6.4 *Room Absorption*:

6.4.1The —The sound absorption in the receiving room should be low in order to achieve the best possible *simulation* of the ideal diffuse field condition, and in order to minimize the region dominated by the direct field of the test specimen. It is recommended that in In the frequency range that extends from f =2000/ = 2000/$V^{1/3}$ to 2000 Hz that the Sabin absorption in the receiving room (as furnished with diffusers) and corrected for air absorption be no greater than the following: to 2000 Hz, the absorption in the receiving room (as furnished with diffusers) should be no greater than:

$$A = V^{2/3}/3 \quad (1)$$

2/3/3

where:

V = the room volume, m^3, and
A = the room absorption in metric sabins.the sound absorption of the room, m^2.

For frequencies below f =2000/$V^{1/3}$, (where the number 2000 is an empirical constant with the units (metres/seconds) somewhat higher absorption may be desirable to accommodate other test requirements (for example, ANSI S1.32, ISO 3741); in any case, the absorption should be no greater than three times the value given by Eq 1.

6.4.1 For frequencies below f = 2000/$V^{1/3}$, somewhat higher absorption may be desirable to accommodate requirements of other test methods (for example, ISO 3741); in any case, the absorption should be no greater than three times the value given by Eq 1.

NOTE4—To minimize errors related to atmospheric absorption, the temperature and humidity in the receiving room should be kept constant during both the transmission and absorption measurements; for monitoring purposes, temperature and humidity should be measured and recorded during each day's testing. (See ANSI S1.26 on air absorption correction.)

6.5The information and recommendations of 6.2-6.4 are provided so that the closest possible approximation to a diffuse sound field will exist in the receiving room. The spatial variations measured in the receiving room shall be such that the precision requirements in 11.3 are satisfied at all frequencies. 3—For frequencies above 2000 Hz, atmospheric absorption may make it impossible to avoid a slightly higher value than that given in Eq 1.

6.5 During the sound pressure level and sound absorption measurements in the receiving room the average temperature shall be in the range 22 ± 5°C and the average relative humidity shall be at least 30 %.

6.6 During the sound pressure level and the corresponding sound absorption measurements, variations in temperature and humidity in the receiving room shall not exceed 3°C and 3 % relative humidity respectively. Temperature and humidity shall be measured and recorded as often as necessary to ensure compliance.

6.6.1 If a relative humidity of at least 30 % can not be maintained in the receiving room, users of the test method shall verify by calculation that changes in the 10 log A_1 term (see 12.4) due to changes in temperature and humidity do not exceed 0.5 dB.

NOTE 4—Procedures for calculating air absorption are described in Test Method C 423.

7. Test Specimens

7.1

7.1 The test specimen shall be prepared and described in the test report in accordance with Annex A1 of Test Method E 90.

7.2 *Size and Mounting*—The test specimen shall include all of the essential constructional elements and surfacing materials normally found in an actual installation. Some elements may have to be reduced in size in order to fit each laboratory's test opening. In the case of precast or preformed solid concrete slabs or hollow-masonry panel structures, it is recommended that the test specimen include two or more complete slabs or panel units. It is recommended that the area of the test specimen be at least 10 m—The test specimen shall have a minimum lateral dimension of 2.4 m. An area of at least 10 m ^{2} and have a minimum dimension of 2.4 m. The test specimen shall be sealed and structurally isolated from the receiving room to avoid significant flanking transmission.

7.2*Aging of Specimens*:

7.2.1Test specimens that incorporate materials for which there is a curing process (for example: adhesives, plasters, concrete, mortar, damping compound) shall age for a sufficient interval before testing. Aging periods for certain common materials are specified in Annex A1. Shorter aging periods may be used if test data indicate that additional aging does not affect acoustical performance (see Note 5).

7.2.2In the case of materials whose aging characteristics are not known, repeated tests over a reasonable time shall be made on at least one specimen to determine an appropriate aging period.

NOTE5—A suggested procedure for determining if a specimen has aged sufficiently is to conduct a series of tests on the specimen after 2, 4, 7, 14 or 28 days of aging. If for two consecutive tests on different days the change in the one-third octave band sound pressure levels at each test frequency is within the range of repeatability for laboratory tests on the same specimen using identical facilities and equipment, then the specimen can be considered to have aged sufficiently.

7.3*Installation of Floor-Surfacing Materials*:

7.3.1Floor-surfacing materials of significant weight, such as carpets and pads, especially when installed with adhesive, may significantly affect the response of the test specimen to impacter, both during test and in normal use. Consequently, such materials should be deemed parts of the test specimen. The materials and the manner of installing them should be fully described (see also 7.3.2 and 7.3.3). The floor-surfacing material should cover the whole test specimen, not merely the portions under the impact machine.

7.3.2The installation or laying of floor-surfacing materials shall be in accordance with manufacturer's instruction, especially in regard to cleaning and priming of the subfloor. It is recommended that flooring materials, including underlayments and adhesives, be stored in an environment similar to that of the source room for at least 72 h before installation, preferably with bundles or cartons broken open. It is recommended that the environmental conditions be regulated to a temperature of 15 to 25°C and a relative humidity of 30 to 60%. The environmental conditions in both the source and receiving rooms should be controlled and recorded.

7.3.3The foregoing procedure is recommended for installation of any flooring material whether by nailing or adhesive techniques. Although most floors are ready for immediate use after being installed, it is recommended that measurements on floors with adhesive-applied surfacing materials be tested no sooner than 24 h after installation to allow the adhesive to cure. For adhesives with undetermined aging periods see Note 3. is recommended. The test specimen shall include all of the essential constructional elements and surfacing materials normally found in an actual installation. Some elements may have to be reduced in size to fit each laboratory's test opening. The test specimen shall be sealed to prevent tapping machine operational sounds from entering the room below. The specimen shall be structurally isolated from the receiving room to avoid significant transmission of vibration from the specimen through the supporting structure to the room below.

7.3 Floor-surfacing materials, such as vinyl, carpets and pads, especially when installed with adhesive, significantly affect the response of the test specimen to impacts, both during test and in normal use. Consequently, such materials shall be deemed parts of the test specimen. The materials and the manner of installing them shall be fully described in the test report. The floor-surfacing material shall cover the whole test specimen, not merely the portion under the impact machine.

8. Tapping Machine

8.1*Specifications*:

8.1.1 This test method is based on the use of a standardized tapping machine that conforms to the specifications given in ISO 140/6. The tapping machine shall have five hammers equally spaced in a line. The distance between centerlines of neighboring hammers shall be100 ± 3 mm. Each hammer shall have an effective mass of 500 ± 6 g which falls freely from a height of 40 ± 3mm. The falling direction of the hammers shall be perpendicular to the test surface to within ± 0.5 °. The part of the hammer carrying the impact surface shall be cylindrical with a diameter of 30 ± 0.2 mm. The impact surface shall be of hardened steel and shall be spherical with a curvature radius of 500 ± 100 mm. The tapping machine shall be self driven. The time between successive impacts shall be 100 ± 20 ms.

8.1.2Since friction in the hammer guidance system can reduce the velocity of the hammer at impact, the tapping machine shall be checked for friction between the hammers and the guidance system. Any friction found should be eliminated or reduced as much as possible. If the friction can not be eliminated, then the hammer weight or drop height can be increased to compensate for this friction. In any event, the hammer weight and drop height shall not exceed the limits given in 8.1.1.

8.1.3In addition, cap the bottoms of the machine mountings or feet with soft sponge-rubber pads about 5 mm thick, and space the feet at least 100 mm from the nearest hammer.

8.1 This test method is based on the use of a standardized tapping machine that conforms to the following specifications:

8.1.1 The tapping machine shall be motor-driven.

8.1.2 The tapping machine shall have five hammers equally spaced in a line. The distance between centerlines of neighboring hammers shall be 100 ± 3 mm.

8.1.3 Each hammer shall have an effective mass of 500 ± 6 g and shall fall freely from a height of 40 ± 3 mm.

8.1.4 The falling direction of the hammers shall be perpendicular to the test surface to within ± 0.5°.

8.1.5 The part of the hammer carrying the impact surface shall be cylindrical with a diameter of 30 ± 0.2 mm.

8.1.6 The impact surface shall be of hardened steel and shall be approximately spherical with a curvature radius of 500 ± 100 mm.

NOTE6—Investigations involving light frame floating floors show that the resiliency of the tapping machine mountings as well as their spacing from the hammers significantly affect the sound pressure levels in the frequency band below 400 Hz. (**5**). The machine may be effectively decoupled from the floor by the use of the sponge rubber pads described in 8.1.3. To determine whether these pads are functioning adequately, place a strip of soft resilient material under the impacting hammers. If, in each frequency band, there is at least a 10 dB reduction in the sound pressure level in the receiving room, the spurious vibrational transmission is negligible. If the reduction is less than 10 dB, the supports must be redesigned and the hammer drop readjusted to conform with the specifications in 8.1.

8.1.4Following adjustment of the hammer drop in accordance with the specifications, the tapping machine is ready for use on any floor structure, including those surfaced with soft or resilient materials.

8.2*Airborne Noise*— The airborne noise radiated by the tapping machine, (in the source room) including that due to the impacting of hammers on the floor surface, shall not contribute to or influence the one-third octave band sound pressure levels measured in the receiving room due to impact noise radiated by the floor/ceiling assembly. One method of dealing with this is to distribute enough sound absorbing material about the source room so that the level of the reverberant sound field is sufficiently reduced. Alternatively, the airborne noise transmission through the specimen under test can be measured to demonstrate that airborne noise does not affect the measurements.

8.3 *5—The mean curvature radius for each hammer face may be determined using a spherometer or other means.*

8.1.7 The time between successive impacts shall be 100 ± 20 ms.

8.1.8 Since friction in the hammer guidance system can reduce the velocity of the hammer at impact, the tapping machine shall be checked for friction between the hammers and the guidance system. Any friction found should be eliminated or reduced as much as possible.

8.1.9 Following adjustment of the hammer drop in accordance with the specifications, the tapping machine is ready for use on any floor structure, including those surfaced with soft or resilient materials.

NOTE 6—The above requirements are a subset of the ISO 140/6 requirements.

8.2 *Tapping Machine Positions*—For conformity, the tapping machine positions and orientations illustrated in —The tapping machine positions and orientations described in the following must be used. Fig. 1 and described below must be used.

8.3.1*illustrates one case.*

8.2.1 *Position 1*—The middle hammer of the tapping machine shall be coincident with the midpoint of the floor area, that is, the point of intersection of floor diagonals. In joistframed construction, adjust this point to the centerline of the closest joist structural member or other support member, and arrange the tapping machine so that all hammers fall on the joist.

8.3.28.2.2 *Position 2*—Same as position 1, except rotate the tapping machine 90° about the axis of the middle hammer.

8.3.3

8.2.3 *Position 3*—Similar to position 1, except displace —Displace the tapping machine laterally from position 1, such that the long dimension of the machine is centered midway between and parallel to the central joists. structural member. In the case of homogeneous concrete slab floors or solid deck construction without joists, the lateral displacement of the tapping machine shall be 0.6 m from that of position 1.

8.3.48.2.4 *Position 4*—Position the tapping machine so that all hammers fall on a 45° radial line extending from the middle hammer point of position 1. Locate the middle hammer 0.6 m from the midpoint of position 1.

9. Measurement of One-Third Octave Band Sound Pressure Levels

9.1The procedure for this method of test is to measure the sound pressure levels in a receiving room located directly below a floor specimen (see 5.1). Measurements of the sound pressure levels shall be made in a specified series of frequency bands for each of the tapping machine positions as designated in 8.3.

9.2*Test Frequency Bands*:

9.2.1The sound pressure levels shall be measured in the 16 contiguous one-third octave bands with center frequencies as follows: 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1000, 1250, 1600, 2000, 2500, and 3150 Hz. It is suggested that additional one-third octave band measurements be made at 50, 63, 80, 4000, and 5000 Hz to accumulate research data.

9.2.2The overall frequency response of the filters used in the microphone system shall, for each test band, conform to the