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Akustika - Merjenje absorpcije zvoka v odmevnici

Acoustics -- Measurement of sound absorption in a reverberation room

Acoustique -- Mesurage de l'absorption acoustique en salle réverbérante

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Acoustics — Measurement of sound absorption in a reverberation room

Acoustique — Mesurage de l'absorption acoustique en salle réverbérante

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

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Acoustics — Measurement of sound absorption in a reverberation room

0 Introduction

When a sound source operates in an enclosed space, the level to which reverberant sound builds up, and the subsequent decay of reverberant sound when the source is stopped, are governed by the sound-absorbing characteristics of the boundary surfaces and objects within the space. In general, the fraction of the incident sound power absorbed at a surface depends upon the angle of incidence. In order to relate the reverberation time of an auditorium, office, workshop, etc. to the noise reduction that would be effected by an absorbing treatment, a knowledge of the sound-absorbing characteristics of the surfaces, usually in the form of a suitable average over all angles of incidence, is required. Since the distribution of sound waves in typical enclosures includes a wide and largely unpredictable range of angles, it is convenient, for the purposes of standardization, to take a uniform distribution as the basic condition. If, furthermore, the sound intensity is independent of location within the room, such a distribution is called a diffuse sound field, and the sounds reaching a room surface are said to be at random incidence.

Measurements under reverberant conditions are necessary because, in this way, the effects of practical mounting conditions can be included. Furthermore, it is the only way to determine the sound absorption of discrete objects such as chairs, office landscaping screens, etc.

The purpose of this International Standard is to promote uniformity in the methods and conditions of measurement of sound absorption in reverberation rooms, so that values determined by different laboratories agree as closely as is possible at present. In order to improve precision, it may become necessary to limit further the variability of test conditions. The sound absorption data determined by the method described may be used for design calculations. In certain cases, however, deviations between predicted and measured values of reverberation time may occur.

It should be emphasized that, in order to attain the above objectives, a more diffuse sound field than the one which ordinarily exists in most rooms, auditoria, etc. is required, and certain other constraints, for example on the dimensions of the reverberation room, are necessary.

1 Scope and field of application

This International Standard specifies a method of measuring the sound absorption coefficient of acoustical materials used as wall or ceiling treatments, or the equivalent sound absorption area of objects, such as furniture, persons or space absorbers, in a reverberation room. It is not intended for measuring the absorption characteristics of weakly damped resonators.

The results obtained can be used for comparison purposes and for design calculation with respect to room acoustics and noise control.

2 References

ISO 5725, *Precision of test methods — Determination of repeatability and reproducibility by inter-laboratory tests.*

IEC Publication 225, *Octave, half-octave and third-octave band filters intended for the analysis of sounds and vibrations.*

3 Definitions

For the purpose of this International Standard, the following definitions apply.

3.1 reverberation time: The time that would be required for the sound pressure level to decrease by 60 dB after the sound source has stopped.

The quantity is denoted by T and is expressed in seconds.

NOTE — This definition is based on the assumption that, in the ideal case, there is a linear relationship between the sound pressure level and time and that the background noise level is sufficiently low.

3.2 equivalent sound absorption area of a room: The hypothetical area of a totally absorbing surface without diffraction effects which, if it were the only absorbing element in the room, would give the same reverberation time as the room under consideration.

For the empty reverberation room, this quantity is denoted by A_1; for the reverberation room containing a test specimen, it is denoted by A_2. The quantity is expressed in square metres.

3.3 equivalent sound absorption area of a test specimen: The difference between the equivalent sound absorption area of the reverberation room with and without the test specimen.

The quantity is denoted by A and is expressed in square metres.

3.4 sound absorption coefficient: The change in equivalent sound absorption area after placing a test specimen in the reverberation room, divided by the area of the test specimen.

It is only defined for a plane test specimen and is denoted by α_S.

NOTE — When evaluating the sound absorption coefficient from measurements in a reverberation room, the results should be denoted by the subscript "S". The use of this subscript avoids confusion with the sound absorption coefficient defined as the ratio of non-reflected-to-incident sound energy if a plane wave strikes a plane wall at a particular angle of incidence. This "geometric" sound absorption coefficient is always smaller than unity and may therefore be expressed as a percentage. The sound absorption coefficient evaluated from reverberation time measurements may have values larger than unity, for example due to diffraction effects, and α_S shall not, therefore, be expressed as a percentage.

3.5 repeatability, r: The value below which the absolute difference between two single test results obtained using the same method on identical test material, under the same conditions (same operator, same apparatus, same laboratory and a short interval of times) may be expected to lie with a specified probability; in the absence of other indications, the probability is 95 %.

3.6 reproducibility, R: The value below which the absolute difference between two single test results obtained using the same method on identical test material, under different conditions (different operators, different apparatus, different laboratories and different times), may be expected to lie with a specified probability; in the absence of other indications, the probability is 95 %.

4 Principle

Measurement of reverberation times in a reverberation room, with and without the test specimen. From these times, calculation of the equivalent sound absorption area A of the test specimen.

In the case of a plane test specimen, the sound absorption coefficient is obtained by dividing A by its surface area S.

When the test specimen comprises several identical objects, the equivalent sound absorption area of an individual object is found by dividing A by the number of objects.

5 Apparatus

The apparatus shall be such that the requirements given in clause 7 are met.

6 Test arrangement

6.1 Reverberation room and diffusion of sound field

6.1.1 Volume of reverberation room

The volume of the reverberation room shall be at least 150 m^3. For new constructions, the volume shall be approximately 200 m^3.

6.1.2 Shape of reverberation room

The shape of the reverberation room should be such that the following condition is fulfilled:

$$l_{max} < 1{,}9\, V^{1/3}$$

where

l_{max} is the length of the longest straight line which fits within the boundary of the room (for example, in a rectangular room, it is the major diagonal);

V is the volume of the room.

In order to achieve a uniform distribution of natural frequencies, especially in the low-frequency bands, no two dimensions of the room shall be equal or in the ratio of small whole numbers.

NOTE — In the case of non-rectangular rooms where the test specimen is placed on the floor, the results will agree more closely with results from rectangular rooms if the non-vertical walls slant inwards.

6.1.3 Diffusion of sound field

The decaying sound field in the room shall be sufficiently diffuse. In order to achieve satisfactory diffusion, whatever the shape of the room, the use of stationary, suspended diffusers or of rotating vanes is, in general, required (see annex A).

6.1.4 Sound absorption area

The equivalent sound absorption area A_1 of the empty room, determined in one-third octave bands, shall not exceed the values given in table 1.

Table 1 — Maximum equivalent sound absorption areas for room volume V = 200 m^3

Equivalent sound absorption area, m^2	6,5	6,5	6,5	7,0	9,5	13,0
Frequency, Hz	125	250	500	1 000	2 000	4 000

If the volume V of the room differs from 200 m^3, the values given in table 1 shall be multiplied by the factor $(V/200)^{2/3}$.

The graph of the equivalent sound absorption area of the empty room versus frequency should be a smooth curve and should have no dips or peaks differing by more than 15 % from the mean of the values of both adjacent one-third octave bands.

6.2 Test specimen

6.2.1 Plane absorbers

6.2.1.1 The test specimen shall have an area between 10 and 12 m^2. If the volume V of the room is greater than 250 m^3, the normal test specimen area shall be increased by the factor $(V/250)^{2/3}$.

NOTE — For the testing of materials with exceptionally small sound absorption coefficients, it is recommended that test specimens with an area larger than specified be used in order to obtain a significant difference between the measured reverberation times T_1 and T_2 (see 8.1.2).

6.2.1.2 The test specimen should be of rectangular shape with a ratio of width to length between 0,7 and 1. It shall be placed so that no part of it is closer than 1 m to any edge of the boundary of the room. The edges of the test specimen should preferably not be parallel to the nearest edge of the room.

6.2.1.3 The test specimen shall be mounted in accordance with the relevant specifications provided by the producer or with the application details provided by the user.

In the case of a test specimen directly mounted on a room surface, the edges shall be totally and tightly enclosed by a frame constructed from reflective material of rectangular cross-section and, in general, of thickness not greater than 2 cm. The frame shall not protrude above the surface of the test specimen. It shall be tightly sealed to the room surface on which it is mounted.

In the case of a test specimen backed by an airgap, for instance to simulate a suspended ceiling, sidewalls shall be constructed perpendicular to the test surface. The sidewalls shall enclose both the airgap and the test specimen edges, and shall be highly reflective.

NOTES

1 The measurement of the reverberation time of the empty room should be made in the absence of the frame or the sidewalls of the test specimen.

2 As an alternative, in the case of test specimens backed by an airgap, the test specimen can be mounted in a recess in one of the boundaries of the reverberation room. It is, however, possible that this method will not give the same results as the method specified.

6.2.2 Discrete sound absorbers

6.2.2.1 Discrete objects, for example chairs, persons, space absorbers, shall be installed for test in the same manner as they are typically installed in practice. For example, chairs or freestanding screens shall rest on the floor, but they shall not be closer than 1 m to any other boundary. Space absorbers shall be mounted at least 1 m from any boundary or room diffusers and at least 1 m from any microphone.

6.2.2.2 A test specimen should comprise a sufficient number of individual objects (in general, at least three) to provide a measurable change in the equivalent sound absorption area of the room greater than 1 m^2, but not more than 12 m^2. If the volume V of the room is greater than 250 m^3, these vaiues shall be increased by the factor 12 $(V/250)^{2/3}$.

Objects normally treated as individual objects should be arranged randomly, spaced at least 2 m apart. If the test specimen comprises only one object, it should be tested in at least three locations, at least 2 m apart, and the results averaged.

6.2.2.3 If the test specimen comprises a given array of objects (for example theatre chairs, noise absorber pads), they shall be installed for test in this configuration. When testing groups of seats with seated persons, the edges of the arrangement shall be enclosed by reflecting material. This enclosure should have a height of up to 1 m. In other cases, the height of the enclosure should be adapted to the height of the test specimen.

6.2.3 Curtains

Curtains tested against walls can be treated as plane absorbers (6.2.1) if closed, or as discrete absorbers (6.2.2) if open. In the former case, the edges shall be enclosed. The requirements for a minimum distance of 1 m from the walls or from the edges do not apply in the case of curtains.

6.3 Temperature and relative humidity

The relative humidity in the room shall be greater than 40 %. During a series of measurements of reverberation times T_1 and T_2 (see 8.1.2), the relative humidity and the temperature should be as constant as possible and at least the conditions given in table 2 should be satisfied.

Table 2 — Requirements for temperature and relative humidity during measurements of T_1 and T_2

Relative humidity range	Relative humidity during all measurements within	Temperature during all measurements within	Lower temperature limit
40 up to 60 %	3 %	3 °C	10 °C
> 60 %	5 %	5 °C	10 °C

The test specimen should be allowed to reach equilibrium with respect to temperature and relative humidity in the room before tests are carried out.

NOTE — Additional correction of the results for the equivalent absorption area A in accordance with 8.1.2, allowing for the energy attenuation in the air, may be applied, but the correction shall not exceed 0,5 m^2 of the equivalent sound absorption area. The method of correction and the origin of the correction data should be given in the test report.

7 Test procedure

7.1 Generation of sound field

The sound in the reverberation room shall be generated by one or more loudspeakers the radiation pattern of which is as non-directional as possible. For frequencies below 300 Hz, measurements should be made with a sound source in at least two successive positions (at least 3 m apart) or with an equivalent multiple source arrangement, the sources not sounding simultaneously unless driven by separate (incoherently related) noise sources.

The test signals shall consist of band-limited noise having a continuous frequency spectrum with a bandwidth of at least one-third octave.

The level of the steady exciting signal before decay shall be sufficiently above the level of the background noise to permit evaluation of the decay curves as specified in 7.2.2.

The exciting signal before being switched off should be sufficiently long to produce a time-constant sound pressure level in the room.

NOTES

1 If a signal with a bandwidth greater than one-third octave is used, long reverberation times in adjacent frequency bands can influence the lower part of the decay curve. If the reverberation times in adjacent bands differ by more than a factor of 1,5, the reverberation times for those bands with the shortest reverberation times should be measured individually using one-third octave filtering of the sound source.

2 Use of wide-band noise and a computer-controlled real-time analyser to make simultaneous measurements for all frequency bands is acceptable, subject to the factors mentioned in note 1. For these measurements with wide-band noise, the average sound spectrum in the room should approximate pink or white noise with differences in sound pressure level less than 6 dB between adjacent one-third octaves.

7.2 Measurement of reverberation time

7.2.1 Receiving equipment

The receiving equipment shall consist of one or more microphones which are as non-directional as possible, the necessary amplifiers, filters and a measuring system for reverberation time.

The recordings shall be made with at least three microphone positions at least $\lambda/2$, apart, where λ is the wavelength of sound for the centre frequency of the frequency band of interest.

Only one microphone shall be used at a time. The microphones shall be at least 1 m from the test specimen, 1 m from room surfaces or diffusers and 2 m from the sound source(s).

The recording system shall be a level recorder or any other adequate equipment for determining the average slope of the decay curve of the corresponding reverberation time.

The apparatus for recording (and displaying and/or evaluating) the decay in sound pressure level may use

a) exponential averaging, with a continuous curve as output; or

b) exponential averaging, with successive discrete sample points from the continuous average as output; or

c) linear averaging, with successive discrete linear averages as output, in some cases with pauses of considerable duration between determinations of averages.

The averaging time of an exponential averaging device (or approximate equivalent; see note 2) shall be less than, but as close as possible to, $T/20$.

The averaging time of a linear averaging device shall be less than $T/7$.

For apparatus in which the decay record is formed as a succession of discrete points, the time interval between points on the record shall be less than 1,5 times the averaging time of the device.

In all cases where the decay record is to be evaluated visually, the time scale of the display should be adjusted so that the slope of the record is as close to 45° as possible.

NOTES

1 The averaging time of an exponential averaging device is equal to 8,69 divided by the decay rate, in decibels per second, of the device.

2 Commercial level recorders in which the sound pressure level is recorded graphically as a function of time are approximately equivalent to exponential averaging devices.

3 When an exponential averaging device is used, there is little advantage in setting the averaging time to very much less than $T/20$. When a linear averaging device is used, there is no advantage in setting the interval between points to very much less than $T/7$. In some sequential measurement procedures, it is feasible to reset the averaging time appropriately for each frequency band. In other procedures, this is not feasible, and an averaging time or interval chosen as above with reference to the smallest reverberation time in any band should be used for measurements in all bands.

One-third octave filters shall be included in the receiving equipment. The discrimination characteristics of the filters shall be in accordance with IEC Publication 225.

7.2.2 Evaluation of decay curves

The reverberation time shall be evaluated from the averaged slope of the decay curve over a convenient range, beginning about 0,1 s after the sound source has been switched off, or from a sound pressure level a few decibels lower than that at the beginning of decay. The range used shall neither be less than 20 dB nor shall it be so large that the observed decay cannot be approximated by a straight line. The bottom of this range shall be at least 15 dB above the combined background noise level of the reverberation room and the recording equipment for each one-third octave band.

A decay may be described as approximately straight if measurements of the slope of two subsections of the curve (each covering a range of at least 10 dB, with one extending to a sound pressure level at least 10 dB lower than the other) do not differ by more than 10 %.

For each combination of microphone and loudspeaker position, and for each one-third octave band, an ensemble averaging procedure, involving the superposition of several repeated excitations of the room, may also be used to obtain a single decay curve from which the reverberation time can be evaluated.

7.3 Frequency ranges for measurements

The measurements shall be carried out at the following centre frequencies, in hertz, from the one-third octave band series:

100	125	160	200	250	315
400	500	630	800	1 000	1 250
1 600	2 000	2 500	3 150	4 000	5 000

7.4 Number of measurements

The minimum number of measurements required for each frequency band is:

a) twelve decays from 100 to 250 Hz (for example, two each of six sound source/microphone combinations);

b) nine decays from 315 to 800 Hz (for example, three each of three sound source/microphone combinations);

c) six decays from 1 000 to 5 000 Hz (for example, two each of three sound source/microphone combinations).

8 Expression of results

8.1 Method of calculation

8.1.1 Calculation of reverberation times T_1 and T_2

The reverberation time of the room in each frequency band is expressed by the arithmetic mean of the total number of reverberation time measurements made in that frequency band.

The mean reverberation times T_1 and T_2 in each frequency band shall be calculated and expressed to at least two decimal places.

8.1.2 Calculation of A_1, A_2 and A

8.1.2.1 The equivalent sound absorption area A_1, in square metres, of the empty reverberation room, shall be calculated using the formula

$$A_1 = \frac{55{,}3\ V}{cT_1}$$

where

V is the volume, in cubic metres, of the empty reverberation room;

c is the velocity of sound in air, in metres per second;

T_1 is the reverberation time, in seconds, of the empty reverberation room.

NOTE — For temperatures in the range 15 to 30 °C, the velocity of sound in air, c, in metres per second, can be calculated from the formula

$$c = 331 + 0{,}6\ t$$

where t is the air temperature, in degrees Celsius.

8.1.2.2 The equivalent sound absorption area A_2, in square metres, of the reverberation room containing a test specimen, shall be calculated using the formula

$$A_2 = \frac{55{,}3\ V}{cT_2}$$

where

c and V have the same meanings as in 8.1.2.1;

T_2 is the reverberation time, in seconds, of the reverberation room after the test specimen has been introduced.

8.1.2.3 The equivalent sound absorption area A, in square metres, of the test specimen, shall be calculated using the formula

$$A = 55{,}3 \frac{V}{c}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

where

c, V and T_1 have the same meanings as in 8.1.2.1;

T_2 has the same meaning as in 8.1.2.2.

NOTE — The area of room surface covered by the test specimen is not taken into account by this formula (see annex B).

8.1.3 Calculation of α_S (see also annex B)

The sound absorption coefficient α_S of a plane absorber shall be calculated using the formula

$$\alpha_S = \frac{A}{S}$$