INTERNATIONAL STANDARD

ISO 354

Second edition
2003-05-15

Acoustics — Measurement of sound absorption in a reverberation room

Acoustique — Mesurage de l'absorption acoustique en salle réverbérante

Reference number
ISO 354:2003(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

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. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 354 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*.

This second edition cancels and replaces the first edition (ISO 354:1985), which has been technically revised, as follows:

— an integrated impulse response method has been introduced;

— the requirement to measure at least 36 decays has been added;

— mounting conditions according to ISO 354:1985:Amd.1:1997 and mounting conditions Type B and Type J have been introduced.

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, the air filling the space, 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, 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, a uniform distribution is taken as the basic condition for the purposes of standardization. If, in addition, the sound intensity is independent of the location within the space, the sound distribution is called a diffuse sound field, and the sounds reaching a room surface are said to be at random incidence.

The sound field in a properly designed reverberation room closely approximates a diffuse field. Hence, sound absorption measured in a reverberation room closely approximates the sound absorption that would be measured under the basic conditions assumed for standardization.

The purpose of this International Standard is to promote uniformity in the methods and conditions of measurement of sound absorption in reverberation rooms.

Acoustics — Measurement of sound absorption in a reverberation room

1 Scope

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 to be used 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 Normative references

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

ISO 266, *Acoustics — Preferred frequencies*

ISO 9613-1, *Acoustics — Attenuation of sound during propagation outdoors — Part 1: Calculation of the absorption of sound by the atmosphere*

IEC 61260, *Electroacoustics — Octave-band and fractional-octave-band filters*

3 Terms and definitions

For the purpose of this document, the following terms and definitions apply.

3.1
decay curve
graphical representation of the decay of the sound pressure level in a room as a function of time after the sound source has stopped

3.2
reverberation time
T
time, in seconds, that would be required for the sound pressure level to decrease by 60 dB after the sound source has stopped

NOTE 1 The definition of T with a decrease by 60 dB of the sound pressure level can be fulfilled by linear extrapolation of shorter evaluation ranges.

NOTE 2 This definition is based on the assumptions 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.

3.3
interrupted noise method
method of obtaining decay curves by direct recording of the decay of the sound pressure level after exciting a room with broadband or band-limited noise

3.4
integrated impulse response method
method of obtaining decay curves by reverse-time integration of the squared impulse responses

3.5
impulse response
temporal evolution of the sound pressure observed at a point in a room as a result of the emission of a Dirac impulse at another point in the room

NOTE It is impossible in practice to create and radiate true Dirac delta functions, but short transient sounds (e.g. from shots) may offer close enough approximations for practical measurements. An alternative measurement technique, however, is to use a period of maximum-length sequence type signal (MLS) or another deterministic, flat-spectrum signal and to transform the measured response back to an impulse response.

3.6
equivalent sound absorption area of a room
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

NOTE 1 The area is measured in square metres.

NOTE 2 For the empty reverberation room, this quantity is denoted by A_1; for the reverberation room containing the test specimen, it is denoted by A_2.

3.7
equivalent sound absorption area of the test specimen
A_T
difference between the equivalent sound absorption area of the reverberation room with and without the test specimen

NOTE The area is measured in square metres.

3.8
area of the test specimen
S
area of the floor or wall covered by the test specimen

NOTE 1 The area is measured in square metres.

NOTE 2 In the case of a test specimen surrounded by a structure (type E mounting or type J mounting), it is the area enclosed by the structure.

3.9
sound absorption coefficient
α_s
ratio of the equivalent sound absorption area of a test specimen divided by the area of the test specimen

NOTE 1 For absorbers where both sides are exposed, the sound absorption coefficient is the equivalent sound absorption area of the test specimen divided by the area of the two sides of the test specimen.

NOTE 2 The sound absorption coefficient evaluated from reverberation time measurements can have values larger than 1,0 (e.g. because of diffraction effects), and α_s is not, therefore, expressed as a percentage.

NOTE 3 The use of the subscript “s” is to avoid 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. That “geometric” sound absorption coefficient is always smaller than 1,0 and may therefore be expressed as a percentage.

4 Principle

The average reverberation time in the reverberation room is measured with and without the test specimen mounted. From these reverberation times, the equivalent sound absorption area of the test specimen, A_T, is calculated by using Sabine's equation (see 8.1.2.1).

In the case of a test specimen that uniformly covers a surface (a plane absorber or a specified array of test objects), the sound absorption coefficient is obtained by dividing A_T by the treated surface area S (see 3.8).

When the test specimen comprises several identical objects, the equivalent sound absorption area A_{obj} of an individual object is found by dividing A_T by the number of objects, n:

$$A_{obj} = A_T/n$$

5 Frequency range

Measurements shall be made in one-third-octave bands with the following centre frequencies, in hertz, as specified in ISO 266:

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

Additional measurements may be made in one-third-octave bands with centre frequencies specified by ISO 266 outside this range. Especially at low frequencies (below 100 Hz), it could be very difficult to obtain accurate measurement results due to the low modal density of the reverberation room.

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 is strongly recommended to be at least 200 m^3. When the volume of the room is greater than about 500 m^3, it may not be possible to measure sound absorption accurately at high frequencies because of air absorption.

6.1.2 Shape of reverberation room

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

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

where

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

V is the volume of the room, in cubic metres.

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

6.1.3 Diffusion of the 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 or suspended diffusers or rotating vanes is, in general, required (see Annex A).

6.1.4 Sound absorption area

The equivalent sound absorption area of the empty room, A_1, calculated according to 8.1.2.1, 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

Frequency, Hz	100	125	160	200	250	315	400	500	630
Equivalent sound absorption area, m^2	6,5	6,5	6,5	6,5	6,5	6,5	6,5	6,5	6,5

Frequency, Hz	800	1 000	1 250	1 600	2 000	2 500	3 150	4 000	5 000
Equivalent sound absorption area, m^2	6,5	7,0	7,5	8,0	9,5	10,5	12,0	13,0	14,0

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

The graph of the equivalent sound absorption area of the empty room versus the frequency shall be a smooth curve and shall 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 specimens

6.2.1 Plane absorbers

6.2.1.1 The test specimen shall have an area between 10 m^2 and 12 m^2. If the volume V of the room is greater than 200 m^3, the upper limit for the test specimen area shall be increased by the factor $(V/200\ \text{m}^3)^{2/3}$.

The area to be chosen depends on the room volume and on the absorption capability of the test specimen. The larger the room, the larger the test area should be. For specimens with small absorption coefficient, the upper limit area should be chosen.

6.2.1.2 The test specimen shall be of rectangular shape with a ratio of width to length of between 0,7 and 1. It should be placed so that no part of it is closer than 1 m to any edge of the boundary of the room; the distance shall be at least 0,75 m. The edges of the specimen shall preferably not be parallel to the nearest edge of the room. If necessary, heavy test specimens may be mounted vertically along the walls of the room, and directly resting on the floor. In this case, the requirement of at least 0,75 m distance need not be respected.

6.2.1.3 The test specimen shall be installed in one of the mountings specified in Annex B, unless the relevant specifications provided by the producer or the application details provided by the user require a different mounting. The measurement of the reverberation time of the empty room shall be made in the absence of the frame or the side walls of the test specimen except for the barrier around a Type J mounting.

6.2.2 Discrete sound absorbers

6.2.2.1 Rectangular unit sound absorber pads or baffles shall be installed in a Type J mounting as specified in Annex B.

6.2.2.2 Discrete objects (e.g. chairs, free-standing screens or persons) shall be installed for the test in the same manner as they are typically installed in practice. For example, chairs or free-standing 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. Office screens shall be mounted as individual objects.

6.2.2.3 A test specimen shall 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 200 m^3, these values shall be increased by the factor $(V/200\ m^3)^{2/3}$. Objects normally treated as individual objects shall be arranged randomly, spaced at least 2 m apart. If the test specimen comprises only one object, it shall be tested in at least three locations, at least 2 m apart, and the results shall be averaged.

6.3 Temperature and relative humidity

6.3.1 Changes in temperature and relative humidity during the course of a measurement can have a large effect on the measured reverberation time, especially at high frequencies and at low relative humidities. The changes are described quantitatively in ISO 9613-1.

6.3.2 Measurements should be performed in the empty room and in the room containing the test specimen under conditions of temperature and relative humidity that are almost the same so that the adjustments due to air absorption do not differ significantly. In any case, the relative humidity in the room shall be at least 30 % and max. 90 % and the temperature shall be at least 15 °C during the whole test. For all measurements, the corrections for the change in air absorption as described in 8.1.2.3 shall be applied.

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

7 Measurement of reverberation time

7.1 General

7.1.1 Introduction

Two methods of measuring decay curves are described in this International Standard: the interrupted noise method and the integrated impulse response method. The decay curve measured with the interrupted noise method is the result of a statistical process, and averaging several decay curves or reverberation times measured at one microphone/loudspeaker position is mandatory in order to obtain a suitable repeatability. The integrated impulse response of a room is a deterministic function and not prone to statistical deviations, so no averaging is necessary. However, it requires more sophisticated instrumentation and data processing than the interrupted noise method.

7.1.2 Microphones and microphone positions

The directivity characteristic of the microphones used for the measurement shall be omnidirectional. The measurements shall be made with different microphone positions which are at least 1,5 m apart, 2 m from any sound source and 1 m from any room surface and the test specimen. Decay curves measured at different microphone positions shall not be combined in any way.

7.1.3 Source positions

The sound in the reverberation room shall be generated by a sound source with an omnidirectional radiation pattern. Different sound source positions which are at least 3 m apart shall be used.