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Acoustics — Measurement of room acoustic parameters —

Part 2:
Reverberation time in ordinary rooms

Acoustique — Mesurage des paramètres acoustiques des salles —
Partie 2: Durée de réverbération des salles ordinaires

Reference number
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Foreword

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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 3382-2 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*.

ISO 3382-2, together with ISO 3382-1 and ISO 3382-3, cancel and replace ISO 3382:1997.

ISO 3382 consists of the following parts, under the general title *Acoustics — Measurement of room acoustic parameters*:

— *Part 1: Performance rooms*

— *Part 2: Reverberation time in ordinary rooms*

The following part is in preparation:

— *Part 3: Open plan spaces*

Introduction

This part of ISO 3382 specifies three levels of measurement accuracy: survey; engineering; and precision. The main difference concerns the number of measurement positions and thus the time required for the measurements. Annex A contains some additional information about the measurement uncertainty of the reverberation time. The introduction of the option of a survey measurement is intended to promote more frequent measurement of reverberation time in rooms where it is relevant. It is obvious that a very simple measurement is better than no measurement.

There are several reasons to measure reverberation time. First, the sound pressure level from noise sources, the intelligibility of speech, and the perception of privacy in a room are strongly dependent on reverberation time. Rooms may include domestic rooms, stairways, workshops, industrial plants, classrooms, offices, restaurants, exhibition centres, sports halls, and railway and airport terminals. Second, reverberation time is measured to determine the correction term for room absorption inherent in many acoustic measurements, such as sound insulation measurements according to ISO 140 (all parts) and sound power measurements according to ISO 3740.

In some countries, building codes specify the required reverberation times in classrooms and other categories of room. However, in the vast majority of rooms, it is left to the design team to specify and design for a reverberation time that is reasonable for the purpose of a room. This part of ISO 3382 is intended to contribute to the general understanding and acceptance of reverberation time for room quality and usability.

Two different evaluation ranges are defined in this part of ISO 3382, 20 dB and 30 dB. However, a preference has been given to the 20 dB evaluation range for several reasons:

a) the subjective evaluation of reverberation is related to the early part of the decay;

b) for the estimation of the steady-state sound level in a room from its reverberation time, it is appropriate to use the early part of the decay: and

c) the signal-to-noise ratio is often a problem in field measurements, and it is often difficult or impossible to get a evaluation range of more than 20 dB. This requires a signal-to-noise level of at least 35 dB.

The traditional measuring technique is based on visual inspection of every single decay curve. With modern measuring equipment, the decay curves are normally not displayed and this may introduce a risk that abnormal decay curves are used for the determination of the reverberation time. For this reason, Annex B introduces two new measures that quantify the degree of non-linearity and the degree of curvature of the decay curve. These measures may be used to give warnings when the decay curve is not linear, and consequently the result should be marked as less reliable and not having a unique reverberation.

The use of rotating microphones during the measurement of decay curves has been considered by the working group, and this procedure is found to be without a clear physical meaning and thus it is only accepted for the interrupted noise method and only when the result is used for a correction term.

For other reverberation time measurements, ISO 3382-1 covers auditoria and performance spaces, and ISO 354 absorption coefficient measurements in a reverberation room. Neither ISO 3382-1 nor ISO 354 is suitable for measurements in rooms like those mentioned above. Thus, this part of ISO 3382 fills a gap among measurement standards for acoustic properties of buildings.

This part of ISO 3382 does not repeat the technical details of ISO 3382-1, but deals with the measurement of reverberation time, only, in any kind of room.

Acoustics — Measurement of room acoustic parameters —

Part 2:
Reverberation time in ordinary rooms

1 Scope

This part of ISO 3382 specifies methods for the measurement of reverberation time in ordinary rooms. It describes the measurement procedure, the apparatus needed, the required number of measurement positions, and the method for evaluating the data and presenting the test report.

The measurement results can be used for correction of other acoustic measurements, e.g. sound pressure level from sound sources or measurements of sound insulation, and for comparison with requirements for reverberation time in rooms.

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 3382-1:—[1)], *Acoustics — Measurement of room acoustic parameters — Part 1: Performance rooms*

ISO 18233, *Acoustics — Application of new measurement methods in building and room acoustics*

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

3 Terms and definitions

For the purposes 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

[ISO 354:2003, 3.1]

NOTE It is possible to measure this decay either after the actual cut-off of a continuous sound source in the room or derived from the reverse-time integrated squared impulse response of the room, see Clause 5.

1) To be published. (Revision of ISO 3382:1997)

3.2
interrupted noise method
method of obtaining decay curves by direct recording of the decay of sound pressure level after exciting a room with broadband or band-limited noise

[ISO 354:2003, 3.3]

3.3
integrated impulse response method
method of obtaining decay curves by reverse-time integration of squared impulse responses

[ISO 354:2003, 3.4]

3.4
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

[ISO 354:2003, 3.5]

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

3.5
reverberation time
T
⟨room acoustic parameters⟩ duration required for the space-averaged sound energy density in an enclosure to decrease by 60 dB after the source emission has stopped

NOTE 1 The reverberation time is expressed in seconds.

NOTE 2 T can be evaluated based on a smaller dynamic range than 60 dB and extrapolated to a decay time of 60 dB. It is then labelled accordingly. Thus, if T is derived from the time at which the decay curve first reaches 5 dB and 25 dB below the initial level, it is labelled T_{20}. If decay values of 5 dB to 35 dB below the initial level are used, it is labelled T_{30}.

3.6
large room volume
an enclosed space of volume greater than 300 m^3

4 Measurement conditions

4.1 General

In many rooms, the number of people present can have a strong influence on the reverberation time. Reverberation time measurements should be made in a room containing no people. However, a room with up to two persons present may be allowed to represent its unoccupied state, unless otherwise specified. If the measurement result is used for correction of a measured sound pressure level, the number of persons present in the room should be the same for that measurement.

In large rooms, attenuation by air can contribute significantly to sound absorption at high frequencies. For precision measurements, the temperature and relative humidity of the air in the room shall normally be measured.

The contribution from air absorption is negligible if the reverberation time is shorter than 1,5 s at 2 kHz and shorter than 0,8 s at 4 kHz. In this case, it is not necessary to measure the temperature and relative humidity.

4.2 Equipment

4.2.1 Sound source

The source should be as omnidirectional as possible. For precision measurements, the directivity of the sound source shall fulfil the requirements of ISO 3382-1:—, A.3.1. For the survey and engineering measurements, there are no specific requirements for the directivity. It shall produce a sound pressure level sufficient to provide decay curves with the required minimum dynamic range without contamination by background noise.

4.2.2 Microphones and analysis equipment

Omnidirectional microphones shall be used to detect sound pressure and the output may be taken either

— directly to an amplifier, filter set and a system for displaying decay curves or analysis equipment for deriving the impulse responses; or

— to a signal recorder for later analysis.

4.2.2.1 Microphone and filters

The microphone should be as small as possible and preferably have a maximum diaphragm diameter of 14 mm. Microphones with diameters up to 27 mm are allowed, if they are of the pressure response type or of the free field response type but supplied with a random incidence corrector. The octave or one-third-octave filters shall conform to IEC 61260.

4.2.2.2 Apparatus for forming decay record of level

The apparatus for forming (and displaying and/or evaluating) the decay record shall use any of the following:

a) exponential averaging, with continuous curve as output;

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

c) linear averaging, with successive discrete linear averages as output.

The averaging time, i.e. time constant of an exponential averaging device, shall be less than, but as close as possible to $T/30$. Similarly, the averaging time of a linear averaging device shall be less than $T/12$. Here T is the reverberation time being measured.

In apparatus where 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, adjust the time scale of the display so that the slope of the record is as close as possible to 45°.

NOTE 1 The averaging time of an exponential averaging device is equal to 4,34 [= 10 lg(e)] divided by the decay rate in decibels per second of the device.

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

NOTE 3 When an exponential averaging device is used, there is little advantage in setting the averaging time very much less than $T/30$. When a linear averaging device is used there is no advantage in setting the interval between points at very much less than $T/12$. In some sequential measuring procedures, it is feasible to set 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 shortest reverberation time in any band has to serve for measurements in all bands.

4.2.2.3 Overload

No overloading shall be allowed in any stage of the measuring apparatus. Where impulsive sound sources are used, peak-level indicating devices shall be used for checking against overloading.

4.3 Measurement positions

4.3.1 General

The minimum numbers of measurement positions to achieve an appropriate coverage in a room are given in Table 1. In rooms with a complicated geometry, more measurement positions should be used. A distribution of microphone-positions shall be chosen which anticipates the major influences likely to cause differences in reverberation time throughout the room.

Table 1 — Minimum numbers of positions and measurements

	Survey	Engineering[a]	Precision
Source-microphone combinations	2	6	12
Source-positions[b]	⩾ 1	⩾ 2	⩾ 2
Microphone-positions[c]	⩾ 2	⩾ 2	⩾ 3
No. decays in each position (interrupted noise method)	1	2	3

[a] When the result is used for a correction term to other engineering-level measurements, only one source-position and three microphone-positions are required.

[b] For the interrupted noise method uncorrelated sources may be used simultaneously.

[c] For the interrupted noise method and when the result is used for a correction term a rotating microphone boom may be used instead of multiple microphone-positions.

For the interrupted noise method, the total number of decays is normally obtained by a number of repeated decays in each position. However, it is also allowed to take a new position for each decay, provided that the total number of decays is as prescribed.

Source-positions may be chosen as the normal position according to the use of the room. In small rooms such as domestic rooms or when no normal positions exist, one source-position should be in a corner of the room. Microphone-positions should preferably be at least half a wavelength apart, i.e. a minimum distance of around 2 m for the usual frequency range. The distance from any microphone-position to the nearest reflecting surface, including the floor, should preferably be at least a quarter of a wavelength, i.e. normally around 1 m. Symmetric positions should be avoided. In the special case of a moving microphone, the sweep radius shall be at least 0,7 m. The plane of the traverse shall not lie within 10° of any plane of the room (wall, floor, ceiling). The duration of a traverse period shall not be less than 15 s.

The microphone-positions shall not be too close together. Otherwise the number of independent positions is less than the actual number of measurement positions. The minimum numbers given in Table 1 are the numbers of independent positions.

No microphone-position shall be too close to any source-position in order to avoid too strong influence from the direct sound. The minimum distance, d_{min}, in metres, can be calculated from Equation (1):

$$d_{\text{min}} = 2\sqrt{\frac{V}{c\hat{T}}} \tag{1}$$

where

V is the volume, in cubic metres;

c is the speed of sound, in metres per second;

$\hat{T}$ is an estimate of the expected reverberation time, in seconds.

4.3.2 Survey method

The survey method is appropriate for the assessment of the amount of the room absorption for noise control purposes, and survey measurements of the airborne and impact sound insulation. It should be used for measurements in ISO 10052. Survey measurements are made in octave bands, only. The nominal accuracy is assumed to be better than 10 % for octave bands, see Annex A.

Make measurements of the reverberation time for at least one source-position. Find the average of results from at least two source-microphone combinations, see Table 1.

4.3.3 Engineering method

The engineering method is appropriate for verification of building performance for comparison with specifications of reverberation time or room absorption. It should be used for measurements in ISO 140 (all parts) with remarks to reverberation time measurements. The nominal accuracy is assumed to be better than 5 % in octave bands and better than 10 % in one-third-octave bands, see Annex A.

Make measurements of the reverberation time for at least two source-positions. At least six independent source-microphone combinations are required, see Table 1.

4.3.4 Precision method

The precision method is appropriate where high measurement accuracy is required. The nominal accuracy is assumed to be better than 2,5 % in octave bands and better than 5 % in one-third-octave bands, see Annex A.

Make measurements of the reverberation time for at least two source-positions. At least 12 independent source-microphone combinations are required, see Table 1.

5 Measurement procedures

5.1 General

Two methods of measuring the reverberation time are described in this part of ISO 3382: the interrupted noise method; and the integrated impulse response method. Both methods have the same expectation value. The frequency range depends on the purpose of the measurements. Where there is no requirement for specific frequency bands, the frequency range should cover at least 250 Hz to 2 000 Hz for the survey method. For the engineering and precision methods, the frequency range should cover at least 125 Hz to 4 000 Hz in octave bands, or 100 Hz to 5 000 Hz in one-third-octave bands.

5.2 Interrupted noise method

5.2.1 Excitation of the room

A loudspeaker source shall be used and the signal fed into the loudspeaker shall be derived from broadband random or pseudo-random electrical noise. When using a pseudo-random noise, it shall be randomly stopped, not using a repeated sequence. The source shall be able to produce a sound pressure level sufficient to ensure a decay curve starting at least 35 dB above the background noise in the corresponding frequency band. If T_{30} is to be measured, it is necessary to create a level at least 45 dB above the background level.

