INTERNATIONAL STANDARD

ISO 16283-2

Third edition
2020-07

Acoustics — Field measurement of sound insulation in buildings and of building elements —

Part 2: Impact sound insulation

Acoustique — Mesurage in situ de l'isolation acoustique des bâtiments et des éléments de construction —

Partie 2: Isolation des bruits d'impacts

Reference number
ISO 16283-2:2020(E)

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 126, *Acoustic properties of building elements and of buildings*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 16283-2:2018), which has been technically revised.

The main changes compared to the previous edition are as follows:

a) Clause 6, Note 3 removed;

b) in the helical path (7.5.5) distance of the microphone position to the ceiling changed to minimum 0,5 m;

c) $L'_{iA,Fmax,V,T}$ added to the expression of results and to Figure C.3.

A list of all parts in the ISO 16283 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

ISO 16283 (all parts) describes procedures for field measurements of sound insulation in buildings. Airborne, impact and façade sound insulation are described in ISO 16283-1, this document (ISO 16283-2) and ISO 16283-3, respectively.

Field sound insulation measurements that were described previously in ISO 140-4[1)], ISO 140-5[2)], and ISO 140-7[3)] were a) primarily intended for measurements where the sound field could be considered to be diffuse, and b) not explicit as to whether operators could be present in the rooms during the measurement. ISO 16283 (all parts) differs from ISO 140-4, ISO 140-5, and ISO 140-7 in that:

a) it applies to rooms in which the sound field may or may not approximate to a diffuse field;

b) it clarifies how operators can measure the sound field using a hand-held microphone or sound level meter;

c) it includes additional guidance that was previously contained in ISO 140-14[4)].

NOTE Survey test methods for field measurements of airborne and impact sound insulation are dealt with in ISO 10052.

Two impact sources are described: the tapping machine and the rubber ball. These impact sources do not exactly replicate all possible types of real impacts on floors or stairs in buildings.

The tapping machine can be used to assess a variety of light, hard impacts such as footsteps from walkers wearing hard-heeled footwear or dropped objects. A single number quantity can be calculated using the rating procedures in ISO 717-2. This single number quantity links the measured impact sound insulation using the tapping machine to subjective assessment of general impacts in dwellings that occur on floors or stairs in a building. The tapping machine is also well-suited to the prediction of impact sound insulation using ISO 12354-2. These two aspects facilitate the specification of impact sound insulation in national building requirements using only measurements with the tapping machine as an impact source.

The rubber ball can be used to assess heavy, soft impacts such as from walkers in bare feet or children jumping, as well as quantifying absolute values that can be related to human disturbance in terms of a Fast time-weighted maximum sound pressure level.

1) Withdrawn.

2) Withdrawn.

3) Withdrawn.

4) Withdrawn.

Acoustics — Field measurement of sound insulation in buildings and of building elements —

Part 2:
Impact sound insulation

1 Scope

This document specifies procedures to determine the impact sound insulation using sound pressure measurements with an impact source operating on a floor or stairs in a building. These procedures are intended for room volumes in the range from 10 m^3 to 250 m^3 in the frequency range from 50 Hz to 5 000 Hz. The test results can be used to quantify, assess and compare the impact sound insulation in unfurnished or furnished rooms where the sound field may or may not approximate to a diffuse field.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 3382-2, *Acoustics — Measurement of room acoustic parameters — Part 2: Reverberation time in ordinary rooms*

ISO 12999-1, *Acoustics — Determination and application of measurement uncertainties in building acoustics — Part 1: Sound insulation*

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

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

IEC 60942, *Electroacoustics — Sound calibrators*

IEC 61183, *Electroacoustics — Random-incidence and diffuse-field calibration of sound level meters*

IEC 61260 (all parts), *Electroacoustics — Octave-band and fractional-octave-band filters*

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
energy-average impact sound pressure level in a room
L_i
ten times the common logarithm of the ratio of the space and time average of the squared sound pressure to the square of the reference sound pressure where the impact source is the tapping machine and the space average is taken over the central zone of the room where nearfield radiation from the room boundaries has negligible influence

Note 1 to entry: L_i is expressed in decibels (dB).

3.2
corner impact sound pressure level in a room
$L_{i,Corner}$
ten times the common logarithm of the ratio of the highest time average squared sound pressure from the set of corner measurements to the square of the reference sound pressure for the low-frequency range (50 Hz, 63 Hz and 80 Hz one-third octave bands) where the impact source is the tapping machine

Note 1 to entry: $L_{i,Corner}$ is expressed in decibels (dB).

3.3
low-frequency energy-average impact sound pressure level in a room
$L_{i,LF}$
ten times the common logarithm of the ratio of the space and time average of the squared sound pressure to the square of the reference sound pressure in the low-frequency range (50 Hz, 63 Hz and 80 Hz one-third octave bands) where the impact source is the tapping machine and the space average is a weighted average that is calculated using the room corners where the sound pressure levels are highest and the central zone of the room where nearfield radiation from the room boundaries has negligible influence

Note 1 to entry: $L_{i,LF}$ is expressed in decibels (dB).

Note 2 to entry: $L_{i,LF}$ is an estimate of the energy-average sound pressure level for the entire room volume.

3.4
energy-average maximum impact sound pressure level in a room
$L_{i,Fmax}$
ten times the common logarithm of the ratio of the space average of the squared maximum sound pressure with Fast time weighting to the square of the reference sound pressure where the impact source is the rubber ball and the space average is taken over the central zone of the room where nearfield radiation from the room boundaries has negligible influence

Note 1 to entry: $L_{i,Fmax}$ is expressed in decibels (dB).

3.5
reverberation time
T
time required for the sound pressure level in a room to decrease by 60 dB after the sound source has stopped

Note 1 to entry: T is expressed in seconds (s).

3.6
background noise level
measured sound pressure level in the receiving room from all sources except the impact source

3.7
fixed microphone
microphone that is fixed in space by using a device such as a tripod so that it is stationary

3.8
mechanized continuously moving microphone
microphone that is mechanically moved with approximately constant angular speed in a circle, or is mechanically swept along a circular path where the angle of rotation about a fixed axis is between 270° and 360°

3.9
manually scanned microphone
microphone attached to a hand-held sound level meter or an extension rod that is moved by a human operator along a prescribed path

3.10
manually held microphone
microphone attached to a hand-held sound level meter or a rod that is hand-held at a fixed position by a human operator at a distance of at least an arm's length from the trunk of the operator's body

3.11
partition
total surface of the floor or stair which is excited by the impact source

Note 1 to entry: For two rooms which are staggered vertically or horizontally, the total surface of the separating partition is not visible from both sides of the partition; hence it is necessary to define the partition as the total surface.

3.12
common partition
part of the floor or stair that is common to both the room in which the impact source is used and the receiving room

3.13
standardized impact sound pressure level
L'_{nT}
energy-average impact sound pressure level (L_i) (3.1), reduced by a correction term that is given in decibels, being ten times the common logarithm of the ratio of the measured *reverberation time* (*T*) (3.5), to the reference reverberation time, T_0, which is calculated using Formula (1) when the impact source is the tapping machine:

$$L'_{nT} = L_i - 10 \lg \frac{T}{T_0} \tag{1}$$

where

T is the reverberation time in the receiving room, in s;

T_0 is the reference reverberation time, in s (for dwellings, T_0 = 0,5 s).

Note 1 to entry: L'_{nT} is expressed in decibels (dB).

Note 2 to entry: The impact sound pressure level is referenced to a *reverberation time* (3.5) of 0,5 s because, in dwellings with furniture, the reverberation time has been found to be reasonably independent of volume and frequency and to be approximately equal to 0,5 s.

Note 3 to entry: L'_{nT} provides a straightforward link to the subjective impression of impact sound insulation.

3.14
equivalent absorption area
A
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* (3.5) as the room under consideration and is calculated using Sabine's formula in Formula (2):

$$A=\frac{0,16V}{T} \tag{2}$$

where

V is the receiving room volume, in m^3;

T is the reverberation time in the receiving room, in s.

Note 1 to entry: A is expressed in square metres (m^2).

3.15
normalized impact sound pressure level
L'_n
energy-average impact sound pressure level (L_i) (3.1), increased by a correction term that is given in decibels, being ten times the common logarithm of the ratio between the measured *equivalent absorption area (A)* (3.14), of the receiving room and the reference equivalent absorption area, A_0, which is calculated using Formula (3) when the impact source is the tapping machine:

$$L'_n=L_i+10\lg\frac{A}{A_0} \tag{3}$$

where

A is the equivalent absorption area in the receiving room, in m^2;

A_0 is the reference equivalent absorption area, in m^2 (for dwellings, A_0 = 10 m^2).

Note 1 to entry: L'_n is expressed in decibels (dB).

3.16
standardized maximum impact sound pressure level
$L'_{i,Fmax,V,T}$
energy-average maximum impact sound pressure level ($L_{i,Fmax}$) (3.4), increased by a correction term for room volume and reduced by a correction term for reverberation time and Fast time weighting, which is calculated using Formulae (4), (5) and (6) when the impact source is the rubber ball:

$$L'_{i,Fmax,V,T}=L_{i,Fmax}+10\lg\frac{V}{V_0}-10\lg\left[\frac{1-C_0^{-1}}{1-C^{-1}}\left(\frac{C^{(1-C)^{-1}}-C^{-\left(1-C^{-1}\right)^{-1}}}{C_0^{(1-C_0)^{-1}}-C_0^{-\left(1-C_0^{-1}\right)^{-1}}}\right)\right] \tag{4}$$

$$C_0=\frac{T_0}{1,7275} \tag{5}$$

$$C=\frac{T}{1,7275} \tag{6}$$

where

T is the reverberation time in the receiving room, in s;

T_0 is the reference reverberation time, in s (for dwellings, T_0 = 0,5 s);

V is the receiving room volume, in m^3;

V_0 is the reference receiving room volume, in m^3 (for dwellings, V_0 = 50 m^3).

Note 1 to entry: $L'_{i,Fmax,V,T}$ is expressed in decibels (dB).

Note 2 to entry: Background information can be found in Reference [1].

4 Instrumentation

4.1 General

The instruments for measuring sound pressure levels, including microphone(s) as well as cable(s), windscreen(s), recording devices and other accessories, if used, shall meet the requirements for a class 0 or 1 instrument in accordance with IEC 61672-1 for random incidence application.

Filters shall meet the requirements for a class 0 or 1 instrument in accordance with IEC 61260 (all parts).

The reverberation time measurement equipment shall comply with the requirements defined in ISO 3382-2.

The impact sources shall meet the requirements given in Annex A.

4.2 Calibration

At the beginning and at the end of every measurement session and at least at the beginning and the end of each measurement day, the entire sound pressure level measuring system shall be checked at one or more frequencies by means of a sound calibrator meeting the requirements for a class 0 or 1 instrument in accordance with IEC 60942. Each time the calibrator is used, the sound pressure level measured with the calibrator should be noted in the field documentation of the operator. Without any further adjustment, the difference between the readings of two consecutive checks shall be less than or equal to 0,5 dB. If this value is exceeded, the results of measurements obtained after the previous satisfactory check shall be discarded.

4.3 Verification

Conformance of the sound pressure level measuring instrument, the filters and the sound calibrator with the relevant requirements shall be verified by the existence of a valid certificate of conformance. If applicable, random incidence response of the microphone shall be verified by a procedure from IEC 61183. All conformance testing shall be conducted by a laboratory meeting the requirements of ISO/IEC 17025 and ensuring metrological traceability to the appropriate measurement standards.

The sound calibrator should be calibrated at intervals not exceeding one year, the conformance of the instrumentation system with the requirements of IEC 61672-1 should be verified at intervals not exceeding two years, and the conformance of the filter set with the requirements of IEC 61260 (all parts) should be verified at intervals not exceeding two years.

5 Frequency range

5.1 Tapping machine as the impact source

All quantities shall be measured using one-third octave band filters having at least the following centre frequencies, in hertz: 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1 000, 1 250, 1 600, 2 000, 2 500, 3 150.

If additional information in the low-frequency range is required, use one-third octave band filters with the following centre frequencies, in hertz: 50, 63, 80.

If additional information in the high-frequency range is required, use one-third octave band filters with the following centre frequencies, in hertz: 4 000, 5 000.

NOTE Measurement of additional information in the low- and high-frequency ranges is optional.

5.2 Rubber ball as the impact source

All quantities shall be measured using one-third octave or octave band filters.

One-third octave band filters shall have at least the following centre frequencies, in hertz: 50, 63, 80, 100, 125, 160, 200, 250, 315, 400, 500, 630.

6 General

To determine the impact sound insulation, one room shall be chosen as the receiving room into which sound is radiated due to an impact source operating on a partition. The room or space in which the impact source is operated is referred to as the source room.

The measurements that shall be performed include the sound pressure levels in the receiving room with the impact source operating, the background noise levels in the receiving room when the impact source is switched off and the reverberation times in the receiving room.

Two impact sources are described: the tapping machine and the rubber ball.

Two measurement procedures are described that shall be used for the sound pressure level, the reverberation time and the background noise: a default procedure and an additional low-frequency procedure.

For the sound pressure level and the background noise, the default procedure requires measurements to be taken in the central zone of a room at positions away from the room boundaries. With the tapping machine as the impact source, the default procedure for all frequencies is to obtain the energy-average sound pressure level using a fixed microphone or a manually held microphone moved from one position to another, an array of fixed microphones, a mechanized continuously moving microphone or a manually scanned microphone. With the rubber ball as the impact source, the default procedure for all frequencies is to obtain the energy-average sound pressure level using a fixed microphone or a manually held microphone moved from one position to another or an array of fixed microphones.

For the sound pressure level and the background noise with the tapping machine as the impact source, the low-frequency procedure shall be used for the 50 Hz, 63 Hz and 80 Hz one-third octave bands in the receiving room when its volume is smaller than 25 m^3 (calculated to the nearest cubic metre). This procedure should be carried out in addition to the default procedure and requires additional measurements of the sound pressure level in the corners of the receiving room using either a fixed microphone or a manually held microphone.

NOTE 1 The low-frequency procedure is necessary in small rooms due to large spatial variations in the sound pressure level of the modal sound field. In these situations, corner measurements are used to improve the repeatability, reproducibility and relevance to room occupants.

NOTE 2 The low-frequency procedure is not used with the rubber ball because no link has yet been shown between any combination of measurements from the corners and central zone of a room for the maximum Fast time-weighted sound pressure level and the maximum Fast time-weighted sound pressure level that is spatially averaged over the entire room volume.

For the reverberation time, the low-frequency procedure shall be used for the 50 Hz, 63 Hz and 80 Hz one-third octave bands in the receiving room when its volume is smaller than 25 m^3 (calculated to the nearest cubic metre).

If the methods of signal processing for reverberation times described in ISO 18233 are applied, the measurements shall be carried out using fixed microphones and shall not use a mechanized continuously moving microphone, a manually held microphone or a manually scanned microphone.

The sound fields in typical rooms rarely approximate to a diffuse sound field over the entire frequency range from 50 Hz to 5 000 Hz. The default and low-frequency procedures allow for measurements to be taken without any knowledge as to whether the sound field can be considered as diffuse or non-diffuse. For this reason, the sound field should not be modified for the purpose of the test by temporarily introducing additional furniture or diffusers into the receiving room.

NOTE 3 If measurements with additional diffusion are required, for example due to regulatory requirements or because the test result is to be compared with a laboratory measurement on a similar test element, the introduction of three diffusers, each with an area of at least 1,0 m^2, is usually sufficient.

All measurement methods for the default procedure or the low-frequency procedure are equivalent. In case of dispute, the impact sound insulation determined using measurement methods without an operator inside the receiving room shall be taken to be the reference result.

NOTE 4 A reference result is defined because the background noise level with manual scanning is prone to variation in the self-generated noise from the operator. Significant variation does not tend to occur with fixed microphones or a mechanized continuously moving microphone.

7 Default procedure for sound pressure level measurement

7.1 General

Sound pressure level measurements shall be used to determine the average level in the central zone of the receiving room with the impact source in operation and the background noise level in the receiving room when the impact source is not operational.

Additional guidance on measurement procedures is given in Annexes D, E and F.

7.2 Generation of sound field

7.2.1 General

The impact sound shall be generated using the tapping machine or the rubber ball as the impact source.

7.2.2 Impact source positions for the tapping machine as impact source

The tapping machine shall be placed in at least four different positions randomly distributed on the floor under test. The distance of the tapping machine from the edges of the floor shall be at least 0,5 m. In the case of anisotropic floor constructions with beams, ribs, etc., more positions can be necessary. The hammer connecting line should be orientated at 45° to the direction of the beams or ribs.

The impact sound pressure levels can reveal a time dependency after the tapping is started. In such a case, the measurements should not begin until the noise level has become steady. If stable conditions are not reached after 5 min, then the measurements should be carried out over a well-defined measurement period. The measurement period shall be reported.

NOTE Time dependency sometimes occurs with soft or fragile floor surfaces as, during each impact, the hammers can change the contact stiffness or damage the surface directly underneath the hammers.

When floors with soft coverings are under test, the tapping machine shall fulfil the special requirements given in Annex A. Advice regarding the mounting of the tapping machine on soft floor coverings is given in Annex A.

7.2.3 Impact source positions for the rubber ball as impact source

The impact sound shall be generated by dropping the rubber ball vertically in a free fall from a height of 100 cm ± 1 cm measured from the bottom of the rubber ball to the surface of the floor under test.

The excitation by the rubber ball shall be made at four or more different positions on the floor or stairs under test. For a lightweight floor with joists, one of these positions should be above the joists and one position should be at the centre point of the floor.

7.3 Fixed microphone positions for the tapping machine or rubber ball as impact source

7.3.1 General

With the tapping machine or the rubber ball as the impact source, fixed microphones may be used without an operator in the room using a microphone fixed on a tripod. Alternatively, the operator may be present in the room with the microphone fixed on a tripod, or with the operator using a manually held microphone at a fixed position; in both cases, the trunk of the operator's body shall remain at a distance of at least an arm's length from the microphone. For the tapping machine as the impact source, the averaging times shall satisfy the requirements in 7.7.1.

Microphone positions shall be distributed within the maximum permitted space throughout each room. No two microphone positions shall lie in the same plane relative to the room boundaries, and the positions shall not be in a regular grid.

7.3.2 Number of measurements

The number of microphone positions shall equal the number of source positions or integer multiples of the number of source positions.

The same number of microphone positions shall be used for each source position.

If four or five source positions are used, at least two measurements of impact sound pressure level shall be made for each source position. Measurements shall be made in at least two different microphone positions for each source position.

If six or more source positions are used, at least one measurement of impact sound pressure level shall be made for each source position. Measurements shall be carried out at a different microphone position for each source position.

7.3.3 Tapping machine operated at more than one position

Measure the sound pressure level in the receiving room for the first impact source position. Calculate the energy-average sound pressure level according to 7.8.1 then make any required correction for background noise according to 9.2. Calculate the standardized impact sound pressure level using Formula (1) or the normalized impact sound pressure level using Formula (3). Repeat this process for the other impact source position(s) then calculate the standardized impact sound pressure level using Formula (7) or the normalized impact sound pressure level using Formula (8):

$$L'_{nT} = 10\lg\left(\frac{1}{m}\sum_{j=1}^{m}10^{\frac{L'_{nT,j}}{10}}\right) \tag{7}$$

$$L'_{n} = 10\lg\left(\frac{1}{m}\sum_{j=1}^{m}10^{\frac{L'_{n,j}}{10}}\right) \tag{8}$$

where

m is the number of tapping machine positions;

$L'_{nT,j}$ is the standardized impact sound pressure level for tapping machine position j;

$L'_{n,j}$ is the normalized impact sound pressure level for tapping machine position j.

7.3.4 Rubber ball operated at more than one position

Measure the sound pressure level in the receiving room for the first impact source position. Calculate the energy-average maximum impact sound pressure level according to 7.8.3, then make any required correction for background noise according to Clause 9. Repeat this process for the other impact source position(s), then calculate the energy-average maximum impact sound pressure level using Formula (9):

$$L_{i,Fmax} = 10\lg\left(\frac{1}{m}\sum_{j=1}^{m}10^{\frac{L_{i,Fmax,j}}{10}}\right) \tag{9}$$

where

m is the number of rubber ball positions;

$L_{i,Fmax,j}$ is the maximum impact sound pressure level for rubber ball position j.

Calculate the standardized maximum impact sound pressure level using Formulae (4), (5) and (6).

7.4 Mechanized continuously moving microphone for the tapping machine as impact source

7.4.1 General

With the tapping machine as the impact source, the microphone shall be mechanically moved with approximately constant angular speed in a circle or shall be mechanically swept along a circular path where the angle of rotation about a fixed axis is between 270° and 360°. The sweep radius for the circular traverse shall be at least 0,7 m. The plane of the traverse shall be inclined in order to cover a large proportion of the permitted room space and shall not lie in any plane that is less than 10° from any room surface (wall, floor or ceiling).

The duration of a single traverse shall be at least 15 s. Each complete traverse may need to be repeated to satisfy the requirements on the averaging time in 7.7.2.

When using at least six tapping machine positions, the location of the fixed point about which the continuously moving microphone moves may be changed.

7.4.2 Number of measurements

The same number of measurements shall be taken for each tapping machine position and at least one measurement shall be made for each tapping machine position.

7.4.3 Tapping machine operated at more than one position

Calculate the standardized impact sound pressure level or the normalized impact sound pressure level as described in 7.3.3.

7.5 Manually scanned microphone for the tapping machine as impact source

7.5.1 General

With the tapping machine as the impact source, the manual-scanning path shall be a circle, a helix, a cylindrical-type path or three semicircles as shown in Figure 1. A circle, helix or cylindrical-type path shall be used in unfurnished or furnished rooms. If there is insufficient space in the room for the operator to use these paths, the path consisting of three semicircles shall be used. Each complete path may need to be repeated to satisfy the requirements on the averaging time in 7.7.3.

When using at least six tapping machine positions, the location of the fixed point from which the manual scan is carried out may be changed.

7.5.2 Number of measurements

The same number of measurements shall be taken for each tapping machine position and at least one measurement shall be made for each tapping machine position.

7.5.3 Tapping machine operated at more than one position

Calculate the standardized impact sound pressure level or the normalized impact sound pressure level as described in 7.3.3.

7.5.4 Circle

The circular path is indicated in Figure 1. The operator shall stand holding the microphone or sound level meter with outstretched arm while rotating the body through an angle of 270° to 360°. The plane of the circle shall be inclined in order to cover a large proportion of the permitted room space and shall not lie in any plane that is less than 10° from any room surface (wall, floor or ceiling). If required, the knees can be bent to reduce the overall height of the microphone; this should always be done when the path is repeated at another position in the room. To minimize operator noise, it can be beneficial to pause the measurement mid-way along the path so that the operator can change the position of the body before continuing the scan.

The operator shall aim to achieve a constant angular speed during the scan. The maximum angular speed shall be approximately 20°/s.

7.5.5 Helix

The helical path is indicated in Figure 1. The operator shall hold the microphone or sound level meter with outstretched arm at a starting position that is 0,5 m above the floor then rotates the body at least twice through 360° from a crouched to a standing position, finishing with the microphone at a position that is at least 0,5 m from the ceiling. To minimize operator noise, it can be beneficial to pause the measurement mid-way along the path so the operator can change the position of the body before continuing the scan.

The operator shall aim to achieve a constant angular speed during the scan. The maximum angular speed shall be approximately 20°/s.

7.5.6 Cylindrical-type

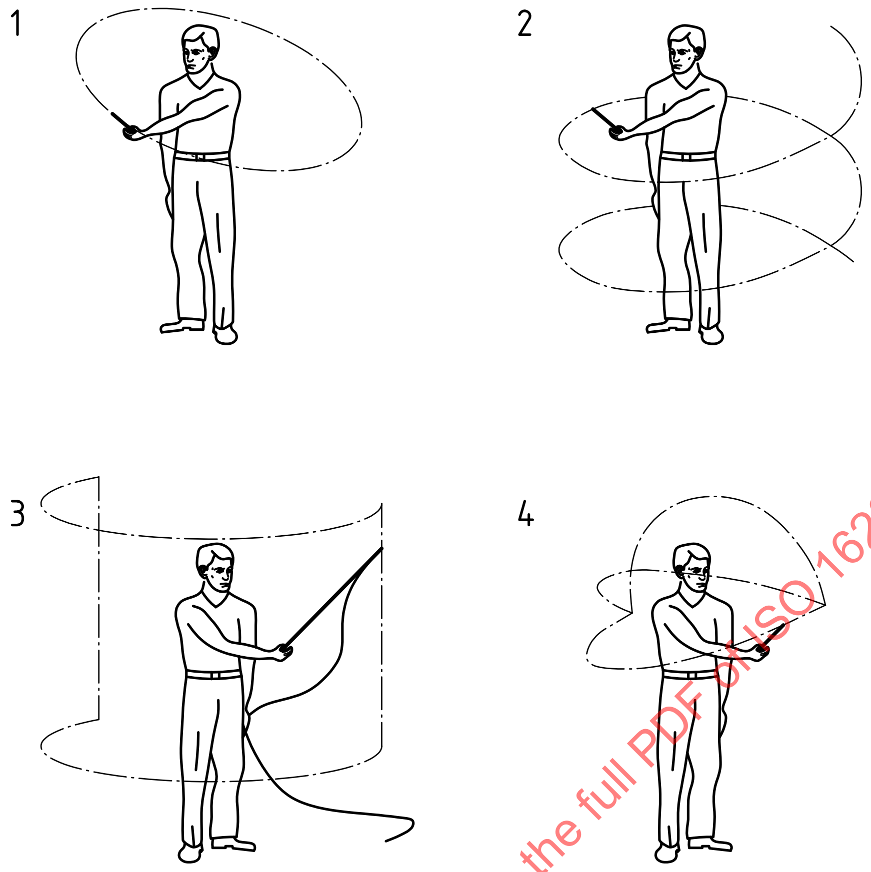
The cylindrical-type path is indicated in Figure 1. The operator shall use a 0,3 m to 0,9 m extension rod to hold the microphone. For a right-handed operator, the path starts 0,5 m above the floor from a position approximately 90° to the left side, the rod is then swept in a circular path parallel to the ground to cover an angle of approximately 220°. The sweep continues vertically upwards along a straight line until the microphone is 0,5 m from the ceiling, after which another circular sweep covers approximately 220° in the opposite direction, before descending to the starting point along a vertical straight line. For a left-handed operator, the directions are reversed.

During the circular sections of the path, the operator shall aim to achieve a constant angular speed. The maximum angular speed shall be approximately 20°/s, with a maximum speed of approximately 0,25 m/s over the straight sections of the path.

7.5.7 Three semicircles

The path comprising three semicircles is indicated in Figure 1. The operator shall stand holding the microphone or sound level meter with an outstretched arm, and trace out three semicircles with approximately 45° to 60° separations. The plane of each semi-circle shall not lie in any plane that is less than 10° from any room surface (wall, floor or ceiling). If required, the knees may be bent to reduce the overall height of the microphone; this should be done when the path is repeated at another position in the room.

For each of the three semicircles, the operator shall aim to achieve a constant angular speed. The maximum angular speed shall be approximately 20°/s.



Key
1 circle
2 helix
3 cylindrical-type
4 three semicircles

Figure 1 — Manual-scanning paths

7.6 Minimum distances for microphone positions

For the default procedure, the following separation distances are minimum values and shall be exceeded where possible:

a) 0,7 m between fixed microphone positions;

b) 0,5 m between any microphone position and the room boundaries;

c) 1,0 m between any microphone position and the partition being excited by the impact source.

7.7 Averaging times for the tapping machine as impact source

7.7.1 Fixed microphone positions

The averaging time at each individual microphone position shall be at least 6 s in the frequency range of 100 Hz to 400 Hz. For 500 Hz to 5 000 Hz, the time may be decreased to not less than 4 s. For 50 Hz to 80 Hz, the averaging time at each individual microphone position shall be at least 15 s.

7.7.2 Mechanized continuously moving microphone

The averaging time shall cover a whole number of complete traverses and shall be at least 30 s for 100 Hz to 5 000 Hz and at least 60 s for 50 Hz to 80 Hz.

7.7.3 Manually scanned microphone

The averaging time shall cover a whole number of complete paths and shall be at least 30 s for 100 Hz to 5 000 Hz, and at least 60 s for 50 Hz to 80 Hz.

7.8 Calculation of energy-average sound pressure levels

7.8.1 Fixed microphone positions for the tapping machine as impact source

The energy-average sound pressure level in the receiving room is determined using Formula (10):

$$L_i = 10 \lg \left(\frac{p_1^2 + p_2^2 + ... + p_n^2}{n p_0^2} \right) \quad (10)$$

where

$p_1{}^2, p_2{}^2, ..., p_n{}^2$ are the mean-square sound pressures at n different microphone positions in the room;

p_0 is the reference sound pressure and is equal to 20 µPa.

In practice, the sound pressure levels are usually measured and the energy-average sound pressure level shall be determined using Formula (11):

$$L_i = 10 \lg \left(\frac{1}{n} \sum_{j=1}^{n} 10^{\frac{L_j}{10}} \right) \quad (11)$$

where $L_1, L_2, ..., L_n$ are the sound pressure levels at n different microphone positions in the room.

7.8.2 Mechanized continuously moving microphone and manually scanned microphone for the tapping machine as impact source

The energy-average sound pressure level in the receiving room is determined using Formula (12):

$$L_i = 10 \lg \left(\frac{\frac{1}{T_m} \int_0^{T_m} p^2(t) \mathrm{d}t}{p_0^2} \right) \quad (12)$$

where

p is the sound pressure, in pascals (Pa);

T_m is the averaging time, in s.

When more than one traverse or scan is carried out in the same room, the energy-average sound pressure level in the room is determined using Formula (13):

$$L_i = 10\lg\left(\frac{10^{\frac{L_1}{10}} + 10^{\frac{L_2}{10}} + \dots + 10^{\frac{L_n}{10}}}{n}\right) \tag{13}$$

where $L_1, L_2, \dots, L_n$ are energy-average sound pressure levels from n different traverses/scans in the room.

7.8.3 Fixed microphone positions for the rubber ball as impact source

For each rubber ball position, j, the energy-average maximum impact sound pressure level, $L_{i,Fmax,j}$, in the receiving room is determined using Formula (14):

$$L_{i,Fmax,j} = 10\lg\left(\frac{1}{n}\sum_{k=1}^{n} 10^{\frac{L_{i,Fmax,j,k}}{10}}\right) \tag{14}$$

where $L_{i,Fmax,j,1}, L_{i,Fmax,j,2}, \dots, L_{i,Fmax,j,n}$ are the maximum sound pressure levels at n different microphone positions in the room for rubber ball position j.

8 Low-frequency procedure for sound pressure level measurement for the tapping machine as impact source

8.1 General

The low-frequency procedure shall be used for the 50 Hz, 63 Hz and 80 Hz one-third octave bands in the receiving room when its volume is smaller than 25 m^3 (calculated to the nearest cubic metre). Sound pressure level measurements are used to determine the highest level in the corners of the receiving room with the tapping machine in operation and the background noise level in the receiving room when the tapping machine is switched off.

8.2 Generation of sound field

8.2.1 General

Sound shall be generated using the standard tapping machine. Requirements for the tapping machine are specified in Annex A.

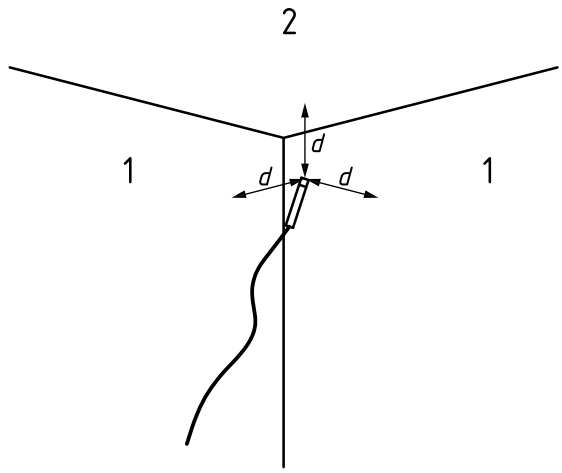
8.2.2 Impact source positions

The tapping machine shall be operated in at least two of the same positions that were used for the default procedure in accordance with the requirements given in 7.2.2.

8.3 Microphone positions

For the low-frequency procedure, a fixed microphone shall be positioned in room corners at a distance of 0,3 m to 0,4 m from each room boundary that forms the corner (see example in Figure 2).

NOTE The distance from each boundary that forms the corner does not need to be identical. For example, it can be positioned at a distance of 0,3 m from one boundary, 0,35 m from another boundary and 0,4 m from the remaining boundary.



Key

1 wall

2 ceiling

d distance

NOTE This is an illustrative example of only one possible corner position in a room.

Figure 2 — Example of a corner microphone position where the distance, *d*, shall be between 0,3 m and 0,4 m

A minimum of four corners shall be measured using a fixed or manually held microphone for each impact source position.

For each set of four corner measurements, two corners should be at ground level and two corners should be at ceiling level. These corners can be adjacent to the partition. Corners shall be used which are formed by three intersecting surfaces (such as walls, doors, windows, floor or ceiling), each having an area of at least 0,5 m^2, that are perpendicular to each other, with no objects such as furniture within 0,5 m of the corner.

Where this is not possible, corners can be used if

— the three intersecting surfaces have angles between pairs of the surfaces between 45° and 135°, and/or

— there are objects close to the three intersecting surfaces, and/or

— an object such as a cupboard forms one of the intersecting surfaces.

For the 50 Hz, 63 Hz and 80 Hz one-third octave bands, calculate the low-frequency energy-average sound pressure level for the source and/or receiving room according to 8.5. Then, calculate the standardized impact sound pressure level using Formula (1) or the normalized impact sound pressure level using Formula (3).

8.4 Averaging time

For the low-frequency procedure, the averaging time at each individual microphone position shall be at least 15 s.

8.5 Calculation of low-frequency energy-average impact sound pressure levels

When the tapping machine is operated at one position (and then further measurements are taken with the tapping machine in different positions), determine the highest sound pressure level from the set of measured corners for each of the 50 Hz, 63 Hz and 80 Hz bands after making any required correction for background noise according to 9.2. For each frequency band, the corner sound pressure level is then calculated from Formula (15):

$$L_{\text{i,Corner}} = 10\lg\left(\frac{p^2_{\text{Corner,TM1}} + p^2_{\text{Corner,TM2}} + ... + p^2_{\text{Corner,TM}q}}{q\, p_0^2}\right) \quad (15)$$

where

$p^2_{\text{Corner,TM1}}$, $p^2_{\text{Corner,TM2}}$, ..., $p^2_{\text{Corner,TM}q}$ are the highest mean-square sound pressures (corrected for background noise where necessary) from corner measurements corresponding to q tapping machine positions;

p_0 is the reference sound pressure and is equal to 20 µPa.

NOTE For each of the 50 Hz, 63 Hz and 80 Hz bands, the mean-square sound pressure values needed to calculate $L_{\text{i,Corner}}$ can be associated with different corners in the room.

The low-frequency energy-average sound pressure level in the 50 Hz, 63 Hz and 80 Hz bands is calculated by combining L_{i} from the default procedure and $L_{\text{i,Corner}}$ from the low-frequency procedure using Formula (16):

$$L_{\text{i,LF}} = 10\lg\left[\frac{10^{0,1 L_{\text{i,Corner}}} + (2 \cdot 10^{0,1 L_{\text{i}}})}{3}\right] \quad (16)$$

9 Background noise (default and low-frequency procedure)

9.1 General

Measurements of background noise levels shall be made to ensure that the signal level in the receiving room is not affected by the background noise and to allow a correction as described in 9.2. Extraneous sound, such as noise from outside the test room, electrical noise in the receiving system, mechanical devices used for the continuously moving microphone and operators inside the test room all contribute to the background noise level.

It is recommended to check that the sound level meter does not introduce spurious signals when pressing buttons which start, pause or stop the measurement.

Operators are a potential source of background noise when using:

a) fixed microphone positions where the operator remains inside the receiving room,

b) manually held microphones, or

c) manually scanned microphones.

Self-generated noise from the operator can result from sources such as clothing, shoes, or arm/knee joints.

For a), b) and c), the operator shall use at least one of the following three methods to try and identify self-generated noise in the receiving room:

1) the time history of the A-weighted sound pressure level (Fast time weighting) to look for unusual transient events;

2) the difference between the maximum sound pressure level with Fast time weighting and the equivalent continuous sound pressure level in frequency bands to indicate unusual transient events;

3) their own hearing, but only when hearing protection is not required and not used.

Using one or more of these methods, operators shall ensure that self-generated noise due to their movement and activity during the sound pressure level measurement of the signal level is similar to that during the background noise measurements.

For manually scanned microphones, the operator shall carry out the background noise measurement using the same type of manual-scanning path that is used for the signal level measurement.

For the low-frequency procedure, a background noise measurement shall be carried out in each corner that is used to calculate the corner sound pressure levels.

NOTE For each of the 50 Hz, 63 Hz and 80 Hz bands, the values for $L_{i,\text{Corner}}$ can be associated with different corners in the room; hence each band can require an individual correction to the signal level for background noise.

The minimum averaging times for the background noise measurement shall satisfy the requirements in 7.7. Using an averaging time that exactly equals these minimum time periods is only appropriate when the background noise is steady and continuous; otherwise, longer averaging times shall be used.

To check the electrical noise in the receiving system, replace the microphone by a dummy microphone.

9.2 Correction to the signal level for background noise

For the default and the low-frequency procedures, the background noise level shall be at least 6 dB (and preferably more than 10 dB) below the level of signal and background noise combined at each frequency band. If the difference in levels is smaller than 10 dB but greater than 6 dB, calculate corrections to the energy-average impact sound pressure level, the corner impact sound pressure level and the energy-average maximum impact sound pressure level using Formula (17):

$$L = 10\lg\left(10^{\frac{L_{sb}}{10}} - 10^{\frac{L_b}{10}}\right) \tag{17}$$

where

L is the adjusted signal level, in dB;

L_{sb} is the level of signal and background noise combined, in dB;

L_b is the background noise level, in dB.

The values for L_{sb} and L_b shall be reduced to one decimal place before use in Formula (17). This is done by taking the value in tenths of a dB closest to the reported values such that XX,XYZZZ… is rounded to XX,X if Y is less than 5 and to XX,X + 0,1 if Y is equal to or greater than 5.

If the difference in levels is less than or equal to 6 dB in any of the frequency bands, use the 1,3 dB correction. For each frequency band where this is the case for the default procedure and/or the low-frequency procedure, it shall be clearly indicated in the report that a 1,3 dB correction has been made and that the values are at the limit of the measurement.

NOTE The energy-average maximum impact sound pressure level that is measured with the rubber ball is not corrected by a background noise level that is described using the maximum sound pressure level. This is due to the difficulty in determining whether the maximum level representing the background noise is likely to have affected the signal level that is measured due to the impact of the rubber ball.

10 Reverberation time in the receiving room (default and low-frequency procedure)

10.1 General

This clause describes the default procedure that shall be used in the receiving room for all reverberation time measurements, and a low-frequency procedure that shall be used when the receiving room volume is smaller than 25 m^3 (calculated to the nearest cubic metre).

The reverberation times shall be measured using the interrupted noise method or the integrated impulse response method as described in ISO 3382-2 and ISO 18233. The engineering method is preferred although the precision method may be used.

Evaluation of the reverberation time from the decay curve shall start at 5 dB below the initial sound pressure level. The preferred evaluation range is 20 dB. The bottom of the evaluation range shall be at least 10 dB above the overall background noise level.

Any operator who was in the receiving room during the sound pressure level measurement shall also be in the receiving room for reverberation time measurements. The operator may be present in the room with the microphone fixed on a tripod or may use a manually held microphone at a fixed position; in both cases, the trunk of the operator's body shall remain at a distance of at least an arm's length from the microphone.

To determine the normalized impact sound pressure level, calculate the equivalent sound absorption area from the reverberation time using Formula (2).

10.2 Generation of sound field

Use loudspeaker(s) at fixed positions that comply with the directivity requirements in Annex B. Loudspeakers may be used simultaneously provided they are of the same type and are driven at the same level by similar, but uncorrelated, signals.

For the default procedure, the sound generated in the room shall be steady and have a continuous spectrum over the frequency range considered. Parallel measurements over the required range of one-third octave bands may be taken using a broadband noise signal. If filtering of the source signal is used for each frequency band under test, use a filter with a corresponding centre-band frequency with a bandwidth of at least one-third octave.

For the low-frequency procedure, the sound generated in the room shall be steady and have a continuous spectrum at least over the frequency range covered by the 63 Hz octave band.

10.3 Default procedure

The default procedure shall use the interrupted noise method described in 10.5 or the integrated impulse response method described in 10.6 for all one-third octave bands between 50 Hz and 5 000 Hz when the receiving room has a volume larger than 25 m^3 (calculated to the nearest cubic metre) and between 100 Hz and 5 000 Hz when the receiving room has a volume smaller than 25 m^3 (calculated to the nearest cubic metre).

10.4 Low-frequency procedure

The low-frequency procedure shall use the interrupted noise method described in 10.5 or the integrated impulse response method described in 10.6 when the receiving room volume is smaller than 25 m^3 (calculated to the nearest cubic metre). This procedure requires that the reverberation time be measured in the 63 Hz octave band instead of the 50 Hz, 63 Hz and 80 Hz one-third octave bands and that this single measured value be used to represent the 50 Hz, 63 Hz and 80 Hz bands in the calculation of L'_{nT}, L'_{n} and/or $L'_{i,Fmax,V,T}$.

NOTE 1 In small room volumes, there are relatively few room modes that determine the decay curve in the 50 Hz, 63 Hz and 80 Hz bands. Hence, the use of 20 dB or 30 dB evaluation ranges on the decay curves from one-third octave bands are prone to error because single-slope decay curves usually only occur when there are many modes in each frequency band. This issue can be partly resolved through use of the 63 Hz octave band filter.

NOTE 2 In timber- or steel-frame buildings with gypsum or timber board linings, the reverberation times in the 50 Hz, 63 Hz and 80 Hz bands can be sufficiently short for the decay curve to be affected by the decay time of the one-third octave band filters in the analyser. This can be avoided by using a 63 Hz octave band filter due to its wider bandwidth which allows the measurement of shorter reverberation times.

10.5 Interrupted noise method

For fixed or manually held microphone positions, the minimum number of measurements required for each frequency band is six. At least one loudspeaker position shall be used with three fixed microphone positions and two measurements at each position, or six fixed microphone positions and one measurement at each position.

For a mechanized continuously moving microphone, the minimum number of measurements required for each frequency band is six. At least one loudspeaker position shall be used with six measurements carried out along the microphone traverse.

10.6 Integrated impulse response method

For the integrated impulse response method, measurement of the reverberation time shall use fixed microphone positions.

Using an impulse source, the minimum number of measurements required for each frequency band is six. At least one source position and six fixed microphone positions shall be used.

The reverberation time shall be calculated by reverse-time integration of the squared impulse response.

11 Conversion to octave bands

For the tapping machine as the impact source, if the standardized impact sound pressure level or the normalized impact sound pressure level is needed in octave bands, these values shall be calculated from the three one-third octave band values in each octave band using Formulae (18) or (19), respectively:

$$L'_{nT,oct} = 10\lg\left(\sum_{n=1}^{3} 10^{\frac{L'_{nT,1/3oct,n}}{10}}\right) \tag{18}$$

$$L'_{n,oct} = 10\lg\left(\sum_{n=1}^{3} 10^{\frac{L'_{n,1/3oct,n}}{10}}\right) \tag{19}$$

For the rubber ball as the impact source, if the standardized maximum impact sound pressure level is needed in octave bands, this value shall be calculated from the three one-third octave band values in each octave band using Formula (20):

$$L'_{i,Fmax,V,T,oct} = 10\lg\left(\sum_{n=1}^{3} 10^{\frac{L'_{i,Fmax,V,T,1/3oct,n}}{10}}\right) \tag{20}$$

The one-third octave band values shall be reduced to one decimal place before use in Formulae (18), (19) and (20). This is done by taking the value in tenths of a dB closest to the reported values such that

XX,XYZZZ… is rounded to XX,X if Y is less than 5 and to XX,X + 0,1 if Y is equal to or greater than 5. Present the final results with no higher precision than to the nearest 0,1 dB.

12 Expression of results

For the statement of the impact sound insulation, the measurement results, L'_{nT}, L'_{n} or $L'_{i,Fmax,V,T}$, shall be given in decibels at all measurement frequencies in one-third octave bands to one decimal place, both in tabular form and in the form of a curve.

Graphs in the test report shall show the value in decibels plotted against frequency on a logarithmic scale; the following dimensions shall be used:

a) 5 mm for a one-third octave band;

b) 20 mm for 10 dB.

The preferred format for the graphs is given in Annex C with the accompanying text stating all relevant information concerning the test site, construction, procedure and results.

13 Uncertainty

The uncertainty of the measurement result shall be determined in accordance with the method given in ISO 12999-1.

14 Test report

The test report shall include at least the following information:

a) a reference to this document and its year of publication (i.e. ISO 16283-2:2019);

b) the name of the organization that has performed the measurements;

c) the name and address of the organization or person who commissioned the test (client);

d) the date of the test;

e) a description and identification of the building construction (address or other unambiguous identifier) and test arrangement (including any temporary modification of the room contents for the test, e.g. the introduction of diffusers; see Clause 6);

f) the volume of the receiving room (calculated to the nearest cubic metre);

g) the impact source;

h) the standardized impact sound pressure level, L'_{nT}, the normalized impact sound pressure level, L'_{n}, or the standardized maximum impact sound pressure level, $L'_{i,Fmax,V,T}$ as a function of frequency;

i) a brief description of the test procedure and of the equipment, indicating if the low-frequency procedure was used for sound pressure level and reverberation time in the 50 Hz, 63 Hz and 80 Hz one-third octave bands;

j) indications of results which are to be taken as limits of measurement. They shall be given as L'_{nT} or L'_{n} or $L'_{i,Fmax,V,T} \leq$…dB. This shall be applied if the sound pressure level in any band is not measurable on account of background noise (see Clause 9).

For the evaluation of single-number ratings from the curves, see ISO 717-2. It shall be clearly stated that the evaluation has been based on a result obtained by a field method. The test report should also include the uncertainty in the single-number rating.

The recommended form for the expression of results is given in Annex C.

Annex A
(normative)

Impact sources

A.1 Standard tapping machine

A.1.1 Requirements

The standard tapping machine shall have five hammers placed in a line. The distance between centrelines of neighbouring hammers shall be (100 ± 3) mm.

The distance between the centre of the supports of the tapping machine and the centrelines of neighbouring hammers shall be at least 100 mm. The supports shall be equipped with vibrational insulating pads.

The momentum of each hammer that strikes the floor shall be that of an effective mass of 500 g which falls freely from a height of 40 mm within tolerance limits for the momentum of ±5 %. As friction of the hammer guidance shall be taken into account, it shall be ensured that not only the mass of the hammer and the falling height, but also the velocity of the hammer at impact, lie within the following limits: the mass of each hammer shall be (500 ± 12) g from which it follows that the velocity at impact shall be (0,886 ± 0,022) m/s. The tolerance limits of the velocity may be increased to a maximum of ±0,033 m/s if it is ensured that the hammer mass lies within accordingly reduced limits of (500 ± 6) g.

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. Testing for fulfilment of this requirement may be performed in the following ways.

a) The curvature of the impact surface is considered to comply with the specifications if the measurement results lie within the tolerances given in Figure A.1 when a meter is moved over the surface on at least two lines through the centre point, the lines being perpendicular to each other.

   The curves of Figure A.1 describe a curvature of 500 mm. The distance between the curves is the smallest distance that allows both the 400 mm and 600 mm radius to fall within the tolerance limits. The accuracy of the measurement shall be at least 0,01 mm.

b) The curvature of the hammer heads may be tested by using a spherometer with three feelers lying on a circle with a diameter of 20 mm.

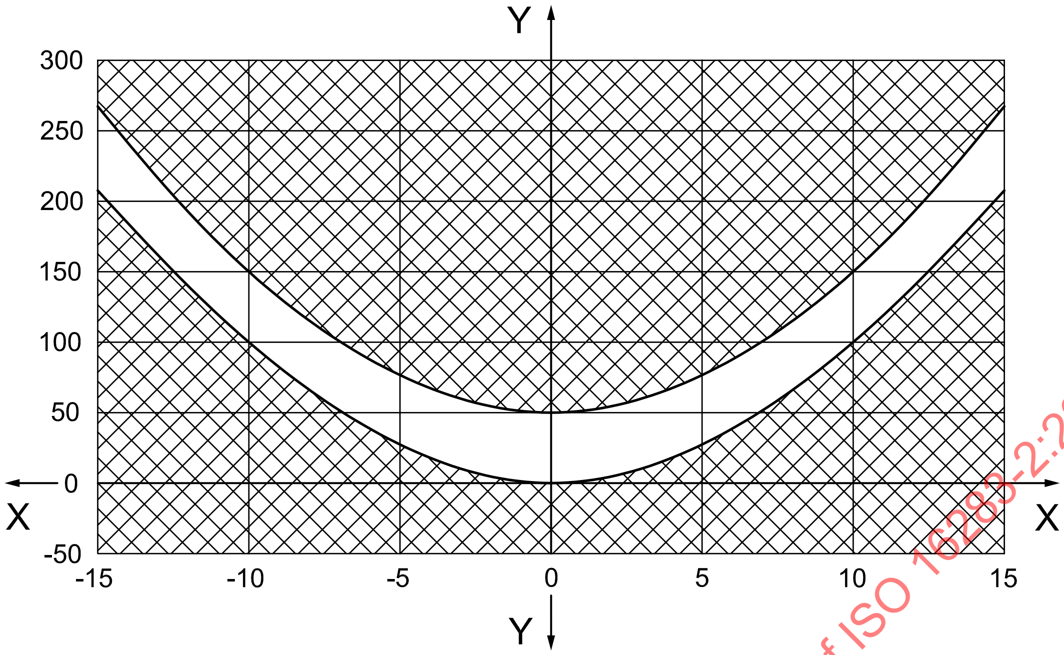
The tapping machine shall be self-driven. The mean time between impacts shall be (100 ± 5) ms. The time between successive impacts shall be (100 ± 20) ms.

The time between impact and lift of the hammer shall be less than 80 ms.

For standard tapping machines that are used for testing impact sound insulation of floors with soft coverings or uneven surfaces, it shall be ensured that it is possible for the hammers to fall at least 4 mm below the plane on which the supports of the tapping machine rest.

All adjustments on the standard tapping machine and verification of the fulfilment of the requirements shall be performed on a flat hard surface and the tapping machine shall be used in that condition on any test surface.

The weight of the tapping machine shall be less than 25 kg in order not to load lightweight floors or floor coverings differently.



Key

X distance from centre (mm)

Y relative height (µm)

NOTE The relative height at the centre can be chosen freely within 0 µm to 50 µm to make the curvature of the hammer head fit within the tolerance limit.

Figure A.1 — Tolerance limits for the curvature of hammer heads

A.1.2 Regular checks of performance

Some of the parameters need to be measured only once, unless the tapping machine has been reconstructed or repaired. This concerns the distance between hammers, supports of the tapping machine, diameter of the hammers, mass of the hammers (unless the hammer heads have been refinished), time between impact and lift, and maximum possible falling height of the hammers.

The velocity of the hammers, diameter and curvature of hammer heads, falling direction of the hammers and time between impacts shall be verified regularly.

The fulfilment of the requirement shall be verified at regular intervals under standard laboratory conditions. The test shall be performed on a test surface that is flat to within ±0,1 mm and horizontal to within ±0,1°.

The uncertainty of the verification measurements shall be at maximum 20 % of the values of the tolerances.

A.2 Rubber ball

A.2.1 Requirements

The rubber ball shall generate the impact force exposure level in each octave band shown in Table A.1 and Figure A.2 when it is dropped vertically in a free fall from the height of 100 cm ± 1 cm measured from the bottom of the rubber ball to the surface of the floor under test.

The impact force exposure level, L_{FE}, is 10 times the common logarithm of the ratio of the time-integrated value of the impact force squared to the square of the reference force, as expressed in decibels by Formula (A.1):

$$L_{FE} = 10 \lg \left[\frac{1}{T_{ref}} \int_{t_1}^{t_2} \frac{F^2(t)}{F_0^2} dt \right] \tag{A.1}$$

where

$F(t)$ is the instantaneous force acted on the floor under test when the rubber ball is dropped on the floor, in newtons (N);

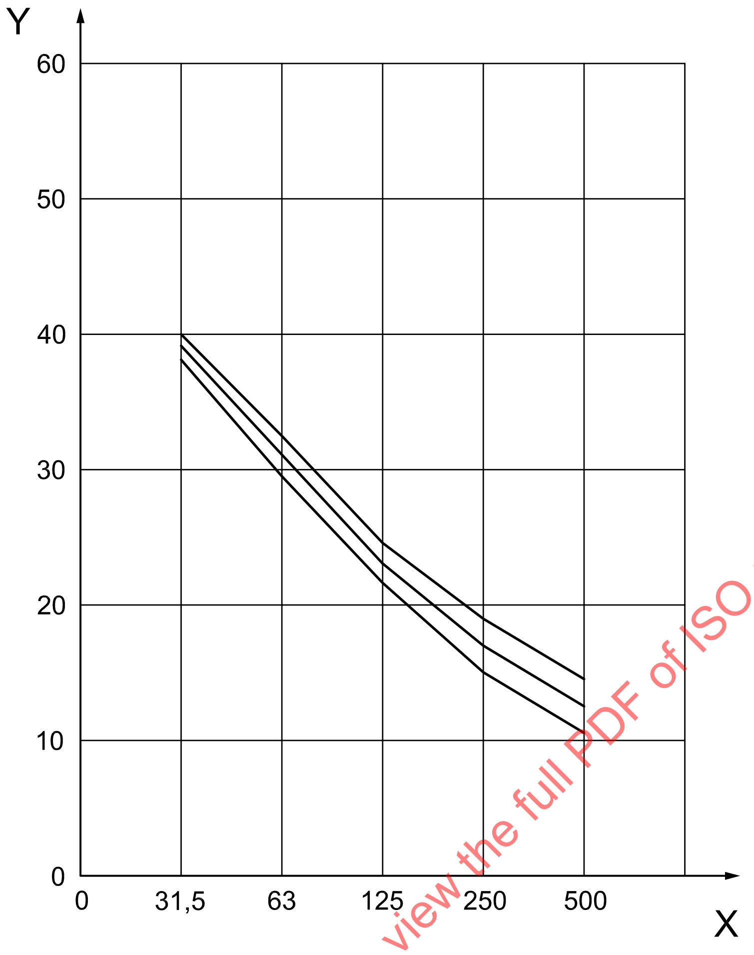
F_0 is the reference force (= 1 N);

$t_2 - t_1$ is the time duration of the impact force, in seconds (s);

T_{ref} is the reference time interval (= 1 s).

Table A.1 — Impact force exposure level in each octave band of the rubber ball

Octave band centre frequency Hz	**Impact force exposure level**, L_{FE} dB re 1 N
31,5	39,0 ± 1,0
63	31,0 ± 1,5
125	23,0 ± 1,5
250	17,0 ± 2,0
500	12,5 ± 2,0



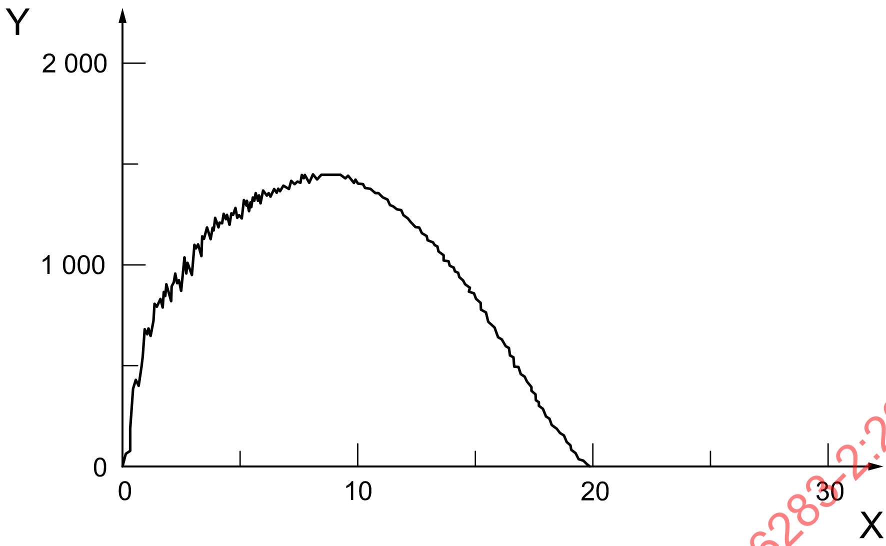
Key

X octave band centre frequency (Hz)

Y impact force exposure level (dB re 1 N)

Figure A.2 — Impact force exposure level in each octave band of the rubber ball

Figure A.3 shows the impact force waveform of the rubber ball.



Key

X time (ms)

Y impact force (N)

NOTE The rubber ball can either be dropped manually or using an automated set-up.

Figure A.3 — Impact force waveform of the rubber ball measured on a heavy concrete floor

A.2.2 Example of construction of the rubber ball

A rubber ball with the following characteristics can realize the conditions specified in A.2.1:

a) shape and size: hollow ball of 180 mm in diameter with 30 mm thickness (see Figure A.4);

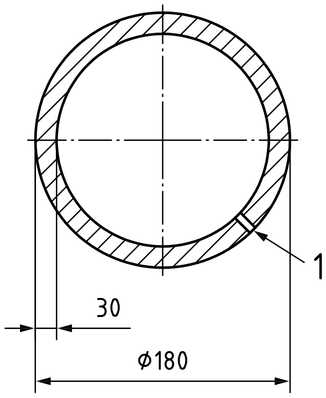
b) composition: see Table A.2;

c) effective mass: (2,5 ± 0,1) kg;

d) coefficient of restitution: 0,8 ± 0,1.

Table A.2 — Composition of the rubber ball

Material	Silicon rubber	Peroxide cross-linking agent	Pigment	Vulcanizing agent
Mass fraction, w_l[a]	100	2	2	<0,1
[a] Parts by mass per hundred parts by mass of rubber.				



Key

1 pin hole (1 mm in diameter)

Figure A.4 — Section view of the rubber ball

A.2.3 Regular checks of performance

The frequency characteristics of the impact force exposure level of the ball only needs to be measured once after manufacture, unless the rubber ball is visibly cracked or damaged.

Annex B
(normative)

Requirements for loudspeakers used for reverberation time measurements

B.1 General

A loudspeaker shall be a closed cabinet containing one or more individual speaker units. All speaker units in the same cabinet shall radiate in phase.

The directivity of loudspeakers shall have approximately uniform, omnidirectional radiation. The qualification procedure for loudspeaker directivity that is described in B.2 shall be used to confirm that the loudspeaker is suitable for measurements.

NOTE In choosing a suitable loudspeaker, it is common to find that loudspeakers mounted on the surfaces of a polyhedron, preferably a dodecahedron, give uniform, omnidirectional radiation. This is also achievable with a hemisphere polyhedron loudspeaker that is mounted directly on the floor.

B.2 Qualification procedure for directivity

To test the directional radiation of a loudspeaker, measure the sound pressure levels around the source at a distance of 1,5 m from the centre of the loudspeaker in a free-field environment. The loudspeaker should be rotated using a turntable or by taking discrete measurements at 5° intervals. The loudspeaker shall be driven with a broadband noise signal, and measurements shall be made in one-third octave bands.

Measure $L_{360°}$, which is the energy-average level for the complete arc of 360°. Measure $L_{30,i}$ values for each angle step, i (typically chosen as 1° or 5° intervals), which correspond to the energy-average value over an arc of 30° that is centred around the angle step (i.e. ±15°). The directivity indices, DI_i, shall be calculated using Formula (B.1):

$$DI_i = L_{360°} - L_{30,i} \quad \text{(B.1)}$$

For one-third octave bands, the loudspeaker(s) can be considered to have uniform omnidirectional radiation if the DI values are within ±2 dB for the frequency range from 100 Hz to 630 Hz, ±5 dB for 800 Hz and ±8 dB for the frequency range from 1 000 Hz to 5 000 Hz.

Carry out the test in different planes to ensure inclusion of the "worst-case" condition. For a polyhedron source, testing in one plane is sufficient.

This qualification procedure shall be carried out at intervals not exceeding two years to ensure conformance.

Annex C
(informative)

Forms for the expression of results

This annex gives examples of forms (see Figure C.1 to C.3) for the expression of results for the field measurements of impact sound insulation between rooms for one-third octave bands. The reference curve values shown in the forms (see Figures C.1 and C.2) are taken from ISO 717-2. The reference curves should be supplemented or at least replaced by the shifted reference curves in accordance with the procedure described in ISO 717-2.

Standardized impact sound pressure levels, L'_{nT}, according to ISO 16283-2

Field measurements of impact sound insulation of floors using the tapping machine

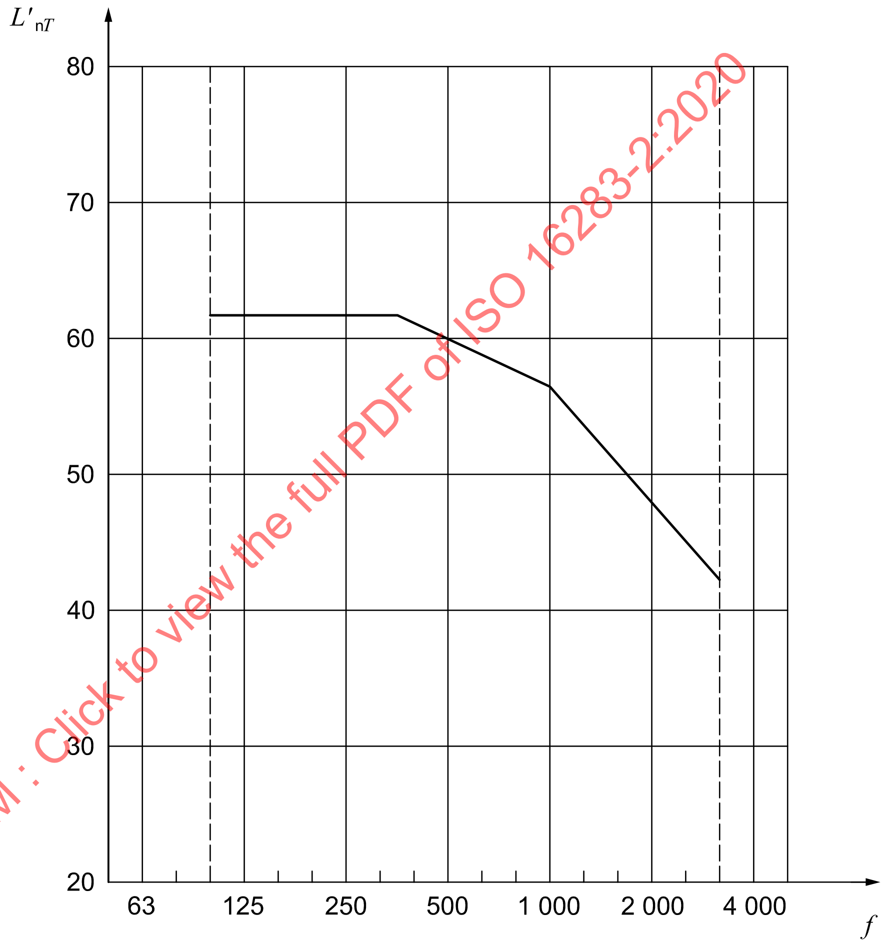
Client:

Date of test:

Description and identification of the building construction and test arrangement, etc.

Receiving room volume: m^3

Frequency f Hz	L'_{nT} dB
50	
63	
80	
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	



– – – – – frequency range for the reference curve

——— reference curve values (ISO 717-2)

Rating in accordance with ISO 717-2:

$L'_{nT,w}(C_I)$ = () dB; $C_{I,50-2\,500}$ = dB

Evaluation based on field measurement results obtained by an engineering method.

No. of test report: Name of test institute:

Date: Signature:

Figure C.1 — Example of a form for the expression of standardized impact sound pressure level results using the tapping machine

Normalized impact sound pressure levels, L'_n, according to ISO 16283-2

Field measurements of impact sound insulation of floors using the tapping machine

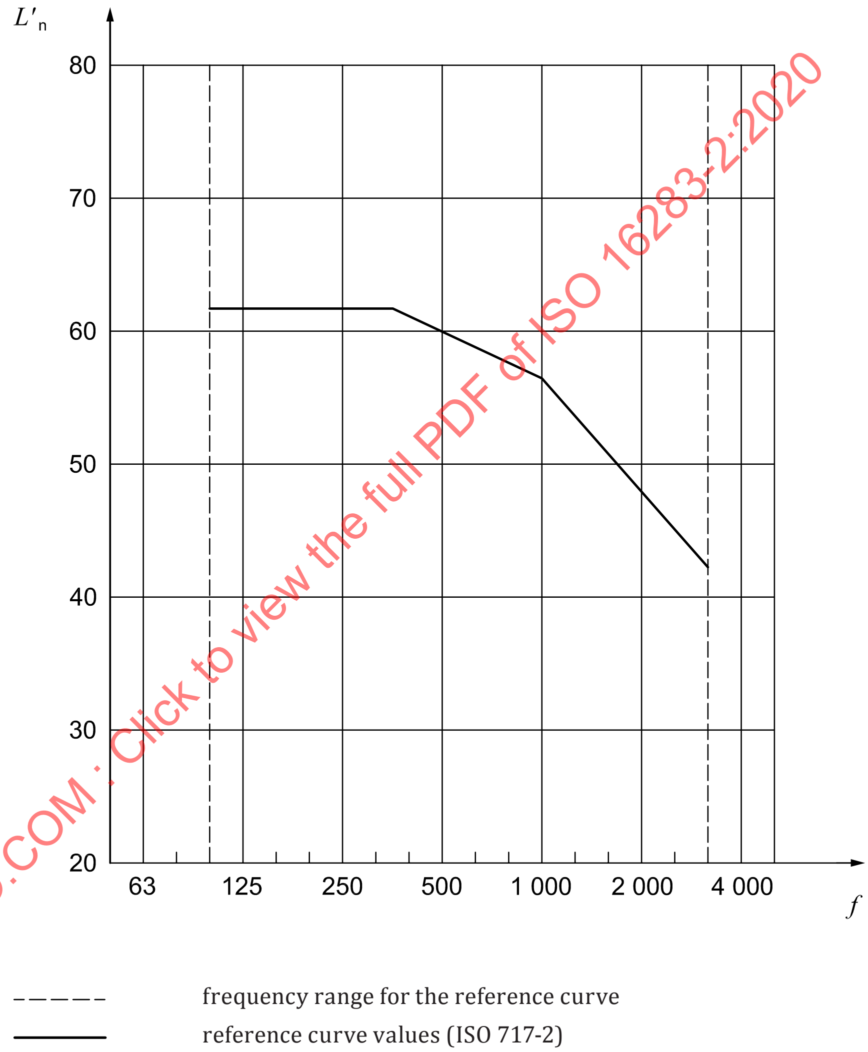
Client:

Date of test:

Description and identification of the building construction and test arrangement, etc.

Receiving room volume: m^3

Frequency f Hz	L'_n dB
50	
63	
80	
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	



Rating in accordance with ISO 717-2:

$L'_{n,w}(C_I)$ = () dB; $C_{I,50-2\,500}$ = dB

Evaluation based on field measurement results obtained by an engineering method.

No. of test report: Name of test institute:

Date: Signature:

Figure C.2 — Example of a form for the expression of normalized impact sound pressure level results using the tapping machine

Standardized maximum impact sound pressure levels, $L'_{i,Fmax,V,T}$, according to ISO 16283-2

Field measurements of impact sound insulation of floors using the rubber ball

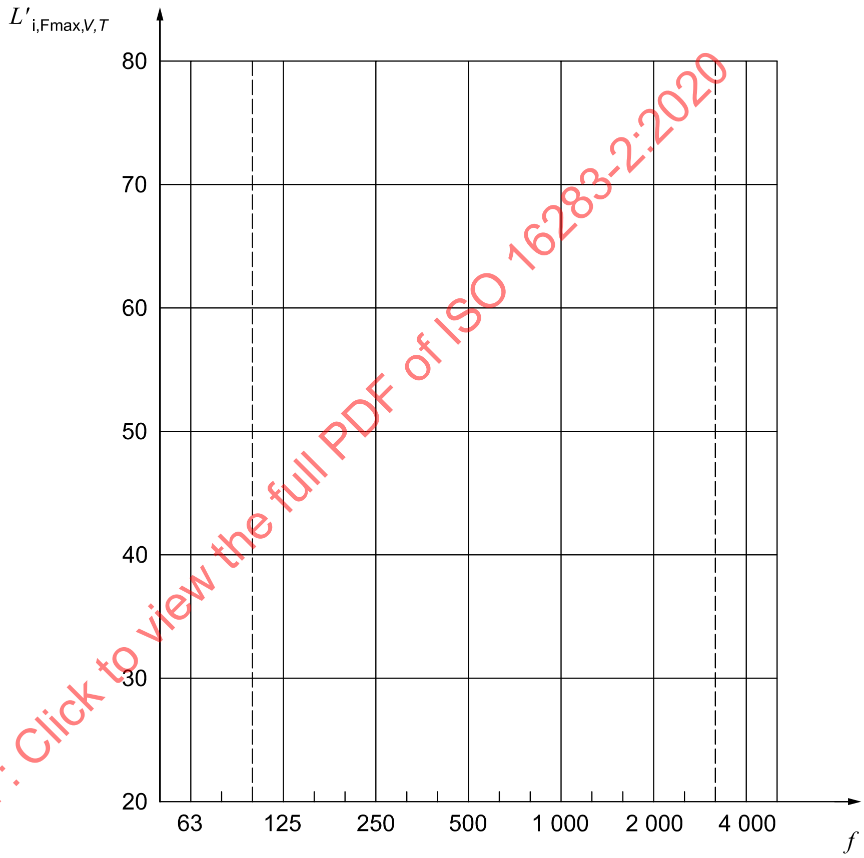
Client:

Date of test:

Description and identification of the building construction and test arrangement, etc.

Receiving room volume: m^3

Frequency f Hz	$L'_{i,Fmax,V,T}$ dB
50	
63	
80	
100	
125	
160	
200	
250	
315	
400	
500	
630	



Rating in accordance with ISO 717-2:

$L'_{iA,Fmax,V,T}$ = () dB

Evaluation based on field measurement results obtained by an engineering method.

No. of test report: Name of test institute:

Date: Signature:

Figure C.3 — Example of a form for the expression of results using the rubber ball

Annex D
(informative)

Additional guidance

D.1 General

This annex contains additional measurement guidelines for room volumes in the range 10 m^3 ≤ V ≤ 250 m^3 in the frequency range 100 Hz to 3 150 Hz. However, the basic principles may also be used for measurements in the frequency range 50 Hz to 80 Hz (when the room volumes are equal to or larger than 25 m^3 calculated to the nearest cubic metre) and in the frequency range 4 000 Hz to 5 000 Hz.

D.2 Principles

D.2.1 Floor coverings

If different floor coverings are used in the same room (e.g. in a combined kitchen and living room), measurements should be performed and reported from the two types of floors separately. The following guidelines should then be used on each of the two floor areas.

Measurements on soft floor coverings (such as carpets and PVC-layers) can be performed on a small sample (e.g. 1 m^2) which is moved between the different tapping machine positions. If the covering is to be fastened by an adhesive, the results from a measurement without adhesive can be misleading. The use of a small sample of a heavy carpet with significant weight on a lightweight timber joist partition should be avoided since it is possible that it does not take into account a damping or restraining effect on the flexural motions of the partition, which occurs when the total area is covered.

When a small sample is used, this should always be mentioned in the test report.

For soft coverings, some materials have an impact sound insulation which is dependent on temperature. The temperature dependence should be evaluated if measurements are carried out under conditions differing from normal temperature.

D.2.2 Calculation of room volumes

When calculating the room volume, the volumes of objects in the receiving room with closed non-absorbing surfaces, such as wardrobes, cabinets and installation shafts, should not be included in the total volume of the receiving room.

D.2.3 Calculation of common partition area

When calculating the area of the common partition, the area should not be reduced by objects such as fixed cabinets or wardrobes that cover part of the common partition.

D.2.4 Number of microphone and impact source positions

The recommended numbers of microphone and impact source positions are given in Table D.1.

Table D.1 — Number of microphone and impact source positions determined from the floor area of the source and receiving rooms

Floor area of the source room m^2	Number of positions	Floor area of the receiving room m^2			
		≤50		>50	
		Partition type 1[a]	**Partition type 2**[b]	**Partition type 1**	**Partition type 2**
<20	Tapping machine	4	4	4	4
	Fixed or manually held microphone positions	4	4	8	8
	Mechanized continuously moving or manually scanned microphone positions	1	1	2	2
20 to 50	Tapping machine	8	4	8	4
	Fixed or manually held microphone positions	4	4	8	8
	Mechanized continuously moving or manually scanned microphone positions	1	1	2	2
>50	Tapping machine	8	8	8	8
	Fixed or manually held microphone positions	4	4	8	8
	Mechanized continuously moving or manually scanned microphone positions	1	1	2	2

[a] Partition type 1: Timber joist partitions, concrete partitions with ribs or beams and solid concrete partitions with a thickness less than 100 mm. Applies to all floor coverings.

[b] Partition type 2: Solid concrete partitions with a thickness equal to or greater than 100 mm, clinker concrete elements and hollow concrete elements. Applies to all floor coverings.

For partition type 1, at least one position of the tapping machine should be on top of a beam with an angle of 45° oriented with the direction of the beam.

For some very small floor areas < 20 m^2, the minimum requirement for the distance between the tapping machine and the edges of the floor leads to a very limited area available for the four tapping machine positions. However, the minimum number of positions stated in Table D.1 should still be used. To achieve this, the tapping machine should be placed within the permitted area and the direction of the hammer connecting line should be changed for each measurement.

D.3 Horizontal measurements

Examples of suitable impact source and microphone positions for horizontal measurements are shown in Annex E.

If the floor area of the source room is equal to or less than 20 m^2, Table D.1 may be used directly. If the floor area exceeds 20 m^2, a limited area of 20 m^2 should be used. The dimensions of the limited floor area perpendicular to the partition in the source room should not be reduced to less than half the width of the partition in the source room. The other dimension of the limited area should not be less than the width of the partition in the receiving room. These recommendations should always be followed. In some special cases, this implies that it will not be possible to limit the floor area to 20 m^2 (see Annex E, Examples 1 to 9).

D.4 Vertical measurements

D.4.1 General

Examples of suitable impact source and microphone positions for vertical measurements are shown in Annex F.

D.4.2 Partly divided rooms

Partly divided rooms can be found in finished buildings (for example an open-plan kitchen/living room which is partly divided by a wall) or unfinished buildings under construction.

For transmission between partly divided rooms in a finished building, the room can be considered as two individual rooms if the area of the opening is equal to or less than one third of the total area of the vertical section of the room in the plane containing the wall (see Annex F, Examples 12 and 13).

For an unfinished building under construction where two rooms are coupled by a large opening, the opening should be covered by sheet material such as plywood or gypsum board to achieve well-defined rooms for the measurement.

D.4.3 Non-staggered rooms

D.4.3.1 General

Non-staggered rooms are defined as rooms where the horizontal contour of the smaller room can be totally contained within the horizontal contour of the larger room.

D.4.3.2 Rooms with floor area of the source room equal to or less than the floor area of the receiving room

The number of tapping machine positions and microphone positions should be chosen directly from Table D.1. The tapping machine positions should be distributed to cover the total floor area (see Annex F, Example 11).

D.4.3.3 Rooms with floor area of the source room larger than the floor area of the receiving room

If the floor area of the source room is equal to or less than 20 m^2, the values of Table D.1 should be used directly. If the floor area of the source room exceeds 20 m^2 and the area of the common partition is equal to or less than 20 m^2, a limited floor area of 20 m^2 should be used for the measurements. The tapping machine should be placed exclusively in this area (see Annex F, Example 14). If the area of the common partition exceeds 20 m^2, the tapping machine positions should be equally distributed over the total area of the common partition.

D.4.4 Staggered rooms

If the area of the common partition is greater than 20 m^2, the guidelines in D.4.3.2 and D.4.3.3 should be used. If the area of the common partition is equal to or less than 20 m^2, or if there is no common part, a limited area of 20 m^2 should be used (see Annex F, Examples 15 to 17).

D.5 Corridors and staircases

D.5.1 Measurements of impact sound insulation from a corridor

Impact sound insulation measurements from a corridor to a room on the same storey or the storey below should be carried out by placing the tapping machine on a limited area of the corridor close to the receiving room. The area used should be the full width of the corridor and a length corresponding to an area of approximately 10 m^2. Four tapping machine positions should be used, and the number of microphone positions should be chosen according to Table D.1 (see Annex E, Example 10).

D.5.2 Measurements of impact sound insulation from staircases in apartment houses and internal stairs in apartments and terrace houses

Measurements should be carried out for the landings and the flights separately. Four tapping machine positions should be used on the landings as well as on the flights. The number of microphone positions should be chosen according to Table D.1.

The four tapping machine positions on the flights should be placed with one at step number two from the top of the flight and one at step number two from the bottom. The other two positions should be evenly distributed in-between the top and bottom positions.

It can sometimes be difficult to place the tapping machine on narrow steps. A special support device may be used to extend the supporting legs at one side of the tapping machine. This allows the machine to stand on two steps. When a special support is used, care should be taken to ensure that the fall height of the hammers and the horizontal balance of the tapping machine are maintained. If such a modification is used, this should be mentioned in the test report. In all cases, care is needed to ensure that the tapping machine does not topple over during operation and cause damage or injury.

The impact sound pressure level from a landing is usually measured in an adjoining room in which the highest level is expected. If the floor in an adjoining room in the same storey as the landing consists of, for example, boards on joists on a concrete slab, the impact sound pressure may be at its highest level in a room in the storey below the landing, because the wooden floor reduces the sound radiation from the concrete slab into the upper room.

If the flights are not fixed to the walls of a staircase, the impact sound pressure level from the flights should be measured in the same room as used for the measurement from the landings. If the flight is fixed to the wall, the receiving room used for measurements from the flight should be chosen as the room closest to the attachment points.

The guidelines stated above are also applicable for measurements on internal stairs (e.g. in a two-storey apartment).

D.6 Airborne sound contribution from the tapping machine

The airborne sound contribution from the tapping machine can be evaluated in the following way.

1) Determine the sound pressure level difference between source and receiving room by means of a pink noise signal from a loudspeaker placed in the source room, $L_{D,spk}$.

2) Measure the sound pressure level in the source room from the tapping machine, $L_{S,tm}$.

3) Measure the sound pressure level in the receiving room from the tapping machine, $L_{R,tm}$.

If the difference, $L_{S,tm} - L_{D,spk}$, is 10 dB or more below $L_{R,tm}$ at any frequency band of interest, the influence of the airborne sound from the tapping machine may be regarded as negligible.