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Acoustics — Laboratory measurement of sound insulation of building elements —

Part 4: Measurement procedures and requirements

Acoustique — Mesurage en laboratoire de l'isolation acoustique des éléments de construction —

Partie 4: Exigences et modes opératoires de mesure

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Contents

Page

Foreword

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

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

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

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

ISO 10140-4 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*.

This first edition of ISO 10140-4, together with ISO 10140-1, ISO 10140-2, ISO 10140-3 and ISO 10140-5, cancels and replaces ISO 140-1:1997, ISO 140-3:1995, ISO 140-6:1998, ISO 140-8:1997, ISO 140-10:1991, ISO 140-11:2005 and ISO 140-16:2006, which have been technically revised.

It also incorporates the Amendments ISO 140-1:1997/Amd.1:2004 and ISO 140-3:1995/Amd.1:2004.

ISO 10140 consists of the following parts, under the general title *Acoustics — Laboratory measurement of sound insulation of building elements*:

— *Part 1: Application rules for specific products*

— *Part 2: Measurement of airborne sound insulation*

— *Part 3: Measurement of impact sound insulation*

— *Part 4: Measurement procedures and requirements*

— *Part 5: Requirements for test facilities and equipment*

Introduction

ISO 10140 (all parts) concerns laboratory measurement of the sound insulation of building elements (see Table 1).

ISO 10140-1 specifies the application rules for specific elements and products, including specific requirements for preparation, mounting, operating and test conditions. ISO 10140-2 and ISO 10140-3 contain the general procedures for airborne and impact sound insulation measurements, respectively, and refer to this part of ISO 10140 and ISO 10140-5 where appropriate. For elements and products without a specific application rule described in ISO 10140-1, it is possible to apply ISO 10140-2 and ISO 10140-3. This part of ISO 10140 contains basic measurement techniques and processes. ISO 10140-5 contains requirements for test facilities and equipment. For the structure of ISO 10140 (all parts), see Table 1.

ISO 10140 (all parts) was created to improve the layout for laboratory measurements, ensure consistency and simplify future changes and additions regarding mounting conditions of test elements in laboratory and field measurements. It is intended for ISO 10140 (all parts) to present a well-written and arranged format for laboratory measurements.

It is intended to update ISO 10140-1 with application rules for other products. It is also intended to incorporate ISO 140-18 into ISO 10140 (all parts).

Table 1 — Structure and contents of ISO 10140 (all parts)

Relevant part of ISO 10140	Main purpose, contents and use	Detailed content
ISO 10140-1	It indicates the appropriate test procedure for elements and products. For certain types of element/product, it can contain additional and more specific instructions about quantities and test element size and about preparation, mounting and operating conditions. Where no specific details are included, the general guidelines are according to ISO 10140-2 and ISO 10140-3.	Appropriate references to ISO 10140-2 and ISO 10140-3 and product-related, specific and additional instructions on: — specific quantities measured; — size of test element; — boundary and mounting conditions; — conditioning, testing and operating conditions; — additional specifics for test report.
ISO 10140-2	It gives a complete procedure for airborne sound insulation measurements according to ISO 10140-4 and ISO 10140-5. For products without specific application rules, it is sufficiently complete and general for the execution of measurements. However, for products with specific application rules, measurements are carried out according to ISO 10140-1, if available.	— Definitions of main quantities measured — General mounting and boundary conditions — General measurement procedure — Data processing — Test report (general points)
ISO 10140-3	It gives a complete procedure for impact sound insulation measurements according to ISO 10140-4 and ISO 10140-5. For products without specific application rules, it is sufficiently complete and general for the execution of measurements. However, for products with specific application rules, measurements are carried out according to ISO 10140-1, if available.	— Definitions of main quantities to measured — General mounting and boundary conditions — General measurement procedure — Data processing — Test report (general points)
ISO 10140-4	It gives all the basic measurement techniques and processes for measurement according to ISO 10140-2 and ISO 10140-3 or facility qualifications according to ISO 10140-5. Much of the content is implemented in software.	— Definitions — Frequency range — Microphone positions — SPL measurements — Averaging, space and time — Correction for background noise — Reverberation time measurements — Loss factor measurements — Low-frequency measurements — Radiated sound power by velocity measurement
ISO 10140-5	It specifies all information needed to design, construct and qualify the laboratory facility, its additional accessories and measurement equipment (hardware).	Test facilities, design criteria: — volumes, dimensions; — flanking transmission; — laboratory loss factor; — maximum achievable sound reduction index; — reverberation time; — influence of lack of diffusivity in the laboratory. Test openings: — standard openings for walls and floors; — other openings (windows, doors, small technical elements); — filler walls in general. Requirements for equipment: — loudspeakers, number, positions; — tapping machine and other impact sources; — measurement equipment. Reference constructions: — basic elements for airborne and impact insulation improvement; — corresponding reference performance curves.

Acoustics — Laboratory measurement of sound insulation of building elements —

Part 4:
Measurement procedures and requirements

1 Scope

This part of ISO 10140 specifies the basic measurement procedures for airborne and impact sound insulation in laboratory test facilities.

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 3382-2, *Acoustics — Measurement of room acoustic parameters — Part 2: Reverberation time in ordinary rooms*

ISO 10140-1:2010, *Acoustics — Laboratory measurement of sound insulation of building elements — Part 1: Application rules for specific products*

ISO 10140-2, *Acoustics — Laboratory measurement of sound insulation of building elements — Part 2: Measurement of airborne sound insulation*

ISO 10140-3, *Acoustics — Laboratory measurement of sound insulation of building elements — Part 3: Measurement of impact sound insulation*

ISO 10140-5:2010, *Acoustics — Laboratory measurement of sound insulation of building elements — Part 5: Requirements for test facilities and equipment*

ISO 10848-1:2006, *Acoustics — Laboratory measurement of the flanking transmission of airborne and impact sound between adjoining rooms — Part 1: Frame document*

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

3 Terms and definitions

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

3.1
energy average sound pressure level in a room
L
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, the space average being taken over the entire room with the

exception of those parts where the direct radiation of a sound source or the near field of the boundaries (walls, etc.) is of significant influence

NOTE L is expressed in decibels.

3.2
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 The reverberation time is expressed in seconds.

NOTE 2 The range evaluated is defined by the times at which the decay curve first reaches 5 dB and 25 dB, respectively, below the initial level.

3.3
structural reverberation time
T_s
time required for the acceleration level in a structure to decrease by 60 dB after the structure-borne sound source has stopped

NOTE 1 The structural reverberation time is expressed in seconds.

NOTE 2 T_s is calculated using linear extrapolation of much shorter evaluation ranges than 60 dB, preferably 15 dB or 20 dB.

3.4
background noise level
measured sound pressure level in the receiving room from all sources other than the loudspeaker or tapping machine in the source room.

3.5
continuously moving microphone
microphone that, with respect to a fixed point,

a) moves with approximately constant speed in a circle, or

b) sweeps to and fro along the arc of a circle, which is as large as possible, but is not be less than 270°, over a fixed time period

4 Measurement procedures and requirements

4.1 Frequency range

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, 4 000, 5 000

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

For additional measurements at low frequencies, guidance is given in Annex A.

4.2 Measurement of sound pressure levels

4.2.1 General

Obtain the energy average sound pressure level using a single microphone moved from position to position, an array of fixed microphones or a continuously moving microphone.

4.2.2 Minimum separation distances for microphone positions

The following separation distances are minimum values and shall be exceeded where possible:

a) 0,7 m between fixed microphone positions;

b) 0,7 m between any microphone position and the room boundaries;

c) 0,7 m between any microphone position and any diffusers;

d) 1,0 m between any microphone position and the test element;

e) 1,0 m between any microphone position and the sound source.

4.2.3 Averaging times

4.2.3.1 Fixed microphone positions

At each individual microphone position, the averaging time shall be at least 6 s for each frequency band, with centre frequencies in the frequency range of 100 Hz to 400 Hz. For bands of higher frequencies, it is permissible to decrease the time to not less than 4 s.

4.2.3.2 Continuously moving microphone

The averaging time shall cover a whole number of traverses and shall not be less than 30 s. Using a moving loudspeaker, the measurement period shall equal the time of movement of the loudspeaker which shall be at least 30 s.

4.2.4 Energy average sound pressure level

4.2.4.1 Fixed microphone positions

The energy average sound pressure level is determined using Equation (1).

$$L = 10 \lg \frac{p_1^2 + p_2^2 + \ldots + p_n^2}{n p_0^2} \qquad (1)$$

where p_1, p_2, ..., p_n are root-mean-square (r.m.s.) sound pressures at n different positions in the room.

In practice, the sound pressure levels are usually measured and the energy average level, L, shall be determined using Equation (2).

$$L = 10 \lg \frac{1}{n} \sum_{j=1}^{n} 10^{L_j/10} \qquad (2)$$

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

4.2.4.2 Continuously moving microphone

The energy average sound pressure level is determined using Equation (3).

$$L = 10\lg \frac{\frac{1}{T_\text{m}}\int_0^{T_\text{m}} p^2(t)\,\text{d}t}{p_0^2} \tag{3}$$

where

p is the sound pressure, in pascals;

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

T_m is the integration time, in seconds.

4.3 Correction for background noise level

Measurements of background noise levels shall be made to ensure that the observations in the receiving room are not affected by the background noise. Extraneous sound, such as noise from outside the test room, electrical noise in the receiving system or electrical cross-talk between the source and the receiving systems all contribute to the background noise level. The background noise level shall be at least 6 dB (and preferably more than 15 dB) below the level of signal and background noise combined at each frequency band.

If the difference in levels is smaller than 15 dB but greater than 6 dB, calculate corrections to the signal level according to Equation (4):

$$L = 10\lg(10^{L_\text{sb}/10} - 10^{L_\text{b}/10}) \tag{4}$$

where

L is the adjusted signal level, in decibels;

L_sb is the level of signal and background noise combined, in decibels;

L_b is the background noise level, in decibels.

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, it shall be clearly indicated in the report that a 1,3 dB correction has been made and these values are the limit of measurement.

To check the electrical noise in the receiving system or electrical cross-talk between the source and the receiving systems, replace the microphone by a dummy microphone or replace the loudspeaker by an equivalent impedance.

4.4 Measurement of airborne sound insulation

4.4.1 General

Sound shall be generated in the source room using loudspeakers in at least two positions or a single loudspeaker moved to at least two positions or a moving loudspeaker. The qualification procedure for loudspeakers and loudspeaker positions is given in ISO 10140-5:2010, Annex D. The sound pressure level shall be measured using microphones in fixed positions or a moving microphone.

4.4.2 Measurements with fixed microphone positions

a) When using more than one loudspeaker at the same time or a moving loudspeaker, a minimum of five microphone positions shall be used in each room. These 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.

b) When using a single loudspeaker, a minimum of five microphone positions shall be used in each room for each loudspeaker position (additional sets of microphone positions may be different from the first set of positions). Each set of 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.

4.4.3 Measurements with a continuously moving microphone

a) When using more than one loudspeaker at the same time or a moving loudspeaker, at least one measurement with a continuously moving microphone shall be used. The sweep radius shall be at least 1 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° to any room surface (wall, floor or ceiling). The duration of a traverse period shall be not less than 15 s.

b) When using a single loudspeaker, a minimum of one measurement using a continuously moving microphone shall be used for each loudspeaker position. The sweep radius shall be at least 1 m. The plane of the traverse shall be inclined to cover a large proportion of the permitted room space and shall not lie in any plane that is less than 10° to a room surface (wall, floor or ceiling). The duration of a traverse period shall be not less than 15 s.

The location of the fixed point about which the continuously moving microphone moves may be changed for each loudspeaker position. The same number of measurements shall be taken at each location.

4.5 Measurement of impact sound insulation

4.5.1 General

Sound shall be generated using the standard tapping machine. Requirements for the tapping machine are specified in ISO 10140-5:2010, Annex E. Not less than four tapping machine positions shall be used for any measurement.

4.5.2 Measurements with fixed microphone positions

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

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

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

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

4.5.3 Continuously moving microphone

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. The sweep radius shall be at least 1 m. The plane of the traverse shall be inclined to cover a large proportion of the permitted room space and shall not lie in any plane that is less than 10° to any room surface (wall, floor or ceiling). The duration of a traverse period shall be not less than 15 s.

The location of the fixed point about which the continuously moving microphone moves may be changed for each tapping machine position. The same number of measurements shall be taken at each location.

4.6 Measurement of reverberation time and evaluation of the equivalent sound absorption area

4.6.1 General

In accordance with ISO 3382-2, the engineering method is the preferred procedure although the precision method may be used. The 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 of the measuring system.

4.6.2 Measurement of reverberation time

Reverberation time shall be measured using the interrupted noise method or the integrated impulse response method as described in ISO 3382-2 and ISO 18233.

The use of an omnidirectional radiating sound source can be beneficial in generating a suitable sound field, but other types of source may be used.

4.6.2.1 Interrupted noise method

For fixed 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 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 distributed along the microphone path.

4.6.2.2 Integrated impulse response method

For the integrated impulse response method, measurement of 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.

4.6.3 Equivalent sound absorption area

Calculate the equivalent sound absorption area, A, in square metres, from the reverberation time using Sabine's formula given in Equation (5).

$$A = \frac{0{,}16\,V}{T} \qquad (5)$$

where

V is the receiving room volume, in cubic metres;

T is the reverberation time, in seconds.

4.7 Measurement of structural reverberation time

The measurement of the structural reverberation time shall be made in accordance with ISO 10848-1:2006, 7.3.

The relation between the total loss factor, η_{total}, and the structural reverberation time, T_s, of the element is given by Equation (6).

$$\eta_{\text{total}} = \frac{2{,}2}{f\,T_s} \qquad (6)$$

where f is the one-third octave band centre frequency in hertz.

The total loss factor includes the internal losses, the structural coupling losses and the radiation losses.

NOTE Lower limits for reliable results caused by filter and detector are given in ISO 10848-1.

4.8 Measurement of radiated sound power by surface velocity of elements

The sound power radiated by the test element and the flanking elements may be used to determine the maximum achievable sound reduction index in the test situation (see ISO 10140-5:2010, Annex A). This can be calculated from vibration measurements on these elements. If the surface velocity of the elements is measured using an accelerometer, it should be securely attached to the surface and its mass impedance should be sufficiently low compared with the driving-point impedance of the element.

If the critical frequency of the test element or of the flanking elements is low compared with the frequency range of interest, the power, W_k, radiated from a particular element, k, with area S_k into the receiving room may be estimated by Equation (7).

$$W_k = \rho c\, S_k\, \overline{v_k^2}\, \sigma_k \qquad (7)$$

where

$\overline{v_k^2}$ is the spatial average, mean square velocity that is normal to the surface;

σ_k is the radiation efficiency, which can be assumed to be equal to 1 above the critical frequency;

ρc is the characteristic impedance of air.

The average surface velocity level, L_v, of the element is given by Equation (8).

$$L_v = 10\,\lg\left(\frac{v_1^2 + v_2^2 + \ldots + v_n^2}{n v_0^2}\right) \qquad (8)$$

where

v_0, v_2, ..., v_n are the r.m.s. normal surface velocities at n different positions on the element;

v_0 is the reference velocity (10^{-9} m/s).

In building acoustics, the reference velocity of 5×10^{-8} m/s is also in use. Therefore, the reference velocity used in Equation (8) should always be stated. The reference vibration velocity of 10^{-9} m/s is preferred for the purposes of this part of ISO 10140.

The spatial average of the mean square of the normal surface velocity in Equation (7) follows from this by Equation (9):

$$\overline{v_k^2} = v_0^2 10^{L_v/10} \tag{9}$$

The accelerometer should be securely attached to the surface and its mass impedance should be sufficiently low compared with the driving-point impedance of the surface.

NOTE Flanking transmission can also be measured using the intensity method (see ISO 15186-1).

5 Sound insulation measurements

5.1 General

Measurements can be conducted using fixed or continuously moving microphones, and moving or fixed loudspeakers.

There shall be no significant change in room absorption between measurements.

It is preferable that simultaneous measurements be made in the source and receiving rooms.

5.2 General procedure for the determination of airborne sound insulation

5.2.1 General

Select one of the following four options described in 5.2.2, 5.2.3, 5.2.4 and 5.2.5.

5.2.2 Fixed microphone positions and multiple loudspeakers operating simultaneously or a moving loudspeaker

Measure the sound pressure levels in both the source and receiving room (see 4.4.2). Calculate the energy average sound pressure level in both the source and receiving rooms [correcting for background noise (see 4.3)] and determine the sound reduction index or element-normalized level difference as given in ISO 10140-2.

5.2.3 Fixed microphone positions and a single loudspeaker operated at more than one position

Measure the sound pressure level in both the source and receiving rooms for the first loudspeaker position (see 4.4.2). Calculate the energy average sound pressure level in both the source and receiving rooms [correcting for background noise (see 4.3)]. Calculate the sound reduction index or element-normalized level difference for this loudspeaker position as given in ISO 10140-2. Both source and receiving room levels shall be measured before the loudspeaker is moved.

Repeat the above procedure for the other loudspeaker positions. Calculate the average sound reduction index or element-normalized level difference using Equation (10) or (11):

$$R = -10 \lg \frac{1}{n} \sum_{i=1}^{n} 10^{-R_i/10} \tag{10}$$

$$D_{n,e} = -10 \lg \frac{1}{n} \sum_{i=1}^{n} 10^{-D_{n,e\,i}/10} \tag{11}$$

5.2.4 Continuously moving microphone and multiple loudspeakers operating simultaneously or a moving loudspeaker

Measure the sound pressure level in both the source and receiving rooms (see 4.4.3). Calculate the energy average sound pressure level in both the source and receiving rooms [correcting for background noise (see 4.3)]. Determine the sound reduction index as given in ISO 10140-2.

NOTE If the moving microphone moves about only one fixed point in each room, the measured levels corrected for background noise are the average energy levels in the source and receiving rooms.

5.2.5 Continuously moving microphone and a single loudspeaker operated at more than one position

Measure the sound pressure level in both the source and receiving rooms for the first loudspeaker position (see 4.4.3). Calculate the energy average sound pressure level in both the source and receiving rooms for the first loudspeaker position [correcting for background noise (see 4.3)]. Calculate the sound reduction index or element-normalized level difference for this loudspeaker position as given in ISO 10140-2. Both source and receiving room levels shall be measured before the loudspeaker is moved.

Repeat the above procedure for the other loudspeaker positions. Calculate the average sound reduction index or element-normalized level difference using Equation (10) or (11), as appropriate.

5.3 General procedure for the determination of impact sound insulation of floors

Measurements may be conducted using fixed or moving microphones and the standard tapping machine.

It shall be ensured that there is no significant change in room absorption between measurements.

The minimum number of tapping machine positions is given in ISO 10140-1:2010, Annex H, or in ISO 10140-3. Each set of measurements shall be made with as many tapping machine positions as are necessary to yield a reliable mean value.

5.3.1 Fixed microphone position

Measure the sound pressure level in the receiving room at each microphone position (see 4.4.2). Calculate the energy average sound pressure level [correcting for background noise level (see 4.3)]. Determine the normalized impact sound pressure level as given in ISO 10140-3.

5.3.2 Continuously moving microphone

Measure the sound pressure level in the receiving room at each moving microphone position (see 4.4.3) Calculate the energy average impact sound pressure level [correcting for background noise level (see 4.3)]. Determine the normalized impact sound pressure level as given in ISO 10140-3.

NOTE If the moving microphone moves about only one fixed point, the measured levels corrected for background noise are the average energy levels in the source and receiving rooms.

Annex A
(informative)

Additional procedures for measurements at low frequencies

A.1 General

In low-frequency bands (below 400 Hz in general and especially below 100 Hz), the sound field in the test rooms is not diffuse, especially when room volumes of only 50 m^3 to 100 m^3 are considered. The general requirement that the room dimensions should be at least one wavelength cannot be fulfilled for the lowest frequency bands.

The excitation of the room modes is highly dependent on the source locations. The sound reduction index depends strongly on which room modes are excited. Even if the repeatability is satisfactory at low frequencies, the reproducibility and comparability with test results from other rooms can be very poor and the test results become dependent on the test facility.

In order to reduce the spread of the measured results, additional effort is necessary with regard to the excitation and sampling of the sound field in the rooms and the special requirements that the rooms have to meet.

Rooms with small volumes and unfavourable dimensions are not usable for low-frequency measurements. At least one room dimension should be of one wavelength and another of at least half a wavelength of the lowest band centre frequency and there should be the space to position the source and the microphones according to the requirements.

A.2 Minimum distances

A significant increase in sound pressure level is measured towards the room boundaries from a distance of about a quarter of a wavelength. The minimum separation distances (see 4.2.2) should therefore be doubled for measurements down to the 50 Hz one-third octave band. For the distance between the microphone positions and the room boundaries, approximately 1,2 m should be the maximum value. This is also valid for the distances between microphone positions and the surface of the test element.

A.3 Sampling of the sound field

In order to obtain a reliable average of the sound pressure levels in the room volume, the number of microphone positions should be increased. The microphone positions should be spread uniformly throughout the allowable volume of the room. If a moving microphone is used, it should sample all parts of the allowable volume as uniformly as possible. At very low frequencies where the room dimensions tend to be in the range of half a wavelength, extremely low sound pressure values are found in the centre part of the room. Therefore, suitable microphone positions should also be found outside this area.

A.4 Loudspeaker positions

The lack of diffusivity in small rooms at low-frequency measurements can be partly compensated by exciting different sound fields one after the other and by averaging the results. Therefore, the number of loudspeaker positions should be increased; the minimum number should be three. The use of a continuously moving loudspeaker is recommended.

