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ISO 140-6

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Acoustics — Measurement of sound insulation in buildings and of building elements —

Part 6:
Laboratory measurements of impact sound insulation of floors

Acoustique — Mesurage de l'isolation acoustique des immeubles et des éléments de construction —

Partie 6: Mesurage en laboratoire de la transmission des bruits de choc par les planchers

Reference number
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Foreword

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

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.

International Standard ISO 140-6 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*.

This second edition cancels and replaces the first edition (ISO 140-6:1978), which has been technically revised.

ISO 140 consists of the following parts, under the general title *Acoustics — Measurement of sound insulation in buildings and of building elements:*

— *Part 1: Requirements of laboratory test facilities with suppressed flanking transmission*

— *Part 2: Determination, verification and application of precision data*

— *Part 3: Laboratory measurement of airborne sound insulation of building elements*

— *Part 4: Field measurements of airborne sound insulation between rooms*

— *Part 5: Field measurements of airborne sound insulation of façade elements and façades*

— *Part 6: Laboratory measurements of impact sound insulation of floors*

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— *Part 7: Field measurements of impact sound insulation of floors*

— *Part 8: Laboratory measurements of the reduction of transmitted impact noise by floor coverings on a heavyweight standard floor*

— *Part 9: Laboratory measurement of room-to-room airborne sound insulation of a suspended ceiling with a plenum above it*

— *Part 10: Laboratory measurement of airborne sound insulation of small building elements*

Annex A forms an integral part of this part of ISO 140. Annexes B to F are for information only.

Acoustics — Measurement of sound insulation in buildings and of building elements —

Part 6:
Laboratory measurements of impact sound insulation of floors

1 Scope

This part of ISO 140 specifies a laboratory method for measuring impact noise transmission through floors by using a standard tapping machine. The method is applicable to bare floors and also to floors with coverings.

The results obtained can be used to compare the impact sound insulation properties of floors and to classify floors according to their sound insulation capabilities.

NOTE 1 Field measurements of impact sound insulation of floors are dealt with in ISO 140-7.

NOTE 2 Laboratory measurements of the reduction of transmitted impact noise by floor coverings on a heavyweight standard floor are dealt with in ISO 140-8.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 140. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 140 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 140-1:1997, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 1: Requirements for laboratory test facilities with suppressed flanking transmission.*

ISO 140-2:1991, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 2: Determination, verification and application of precision data.*

ISO 354:1985, *Acoustics — Measurement of sound absorption in a reverberation room.*

ISO 717-2:1996, *Acoustics — Rating of sound insulation in buildings and of building elements — Part 2: Impact sound insulation*.

IEC 60651:1979, *Sound level meters.*

IEC 60804:1985, *Integrating-averaging sound level meters.*

IEC 60942: 1988, *Sound calibrators.*

IEC 61260:1995, *Electroacoustics — Octave band filters and fractional — Octave band filters.*

3 Definitions

For the purpose of this part of ISO 140, the following definitions apply.

3.1 average sound pressure level in a room, L: Ten times the logarithm to the base 10 of the ratio of the space and time average of the sound pressure squared 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 (wall, etc.) is of significant influence; it is expressed in decibels.

If a continuously moving microphone is used, L is determined by

$$L = 10 \lg \frac{\frac{1}{T_m} \int_0^{T_m} p^2(t)\,dt}{p_0^2} \text{ dB} \qquad \ldots (1)$$

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.

If fixed microphone positions are used, L is determined by

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

where p_1, p_2..., p_n are r.m.s. sound pressures at n different positions in the room. In practice, usually the sound pressure levels L_j are measured. In this case L is determined by

$$L = 10 \lg \left(\frac{1}{n} \sum_{j=1}^{n} 10^{L_j/10} \right) \text{ dB} \qquad \ldots (3)$$

where L_j are the sound pressure levels L_1 to L_n at n different positions in the room.

3.2 impact sound pressure level, L_i: Average sound pressure level in a one-third-octave band in the receiving room when the floor under test is excited by the standardized impact sound source; it is expressed in decibels.

3.3 normalized impact sound pressure level, L_n: Impact sound pressure level L_i increased by a correction term which is given in decibels, being ten times the logarithm to the base 10 of the ratio of the measured equivalent absorption area A of the receiving room to the reference absorption area A_0; it is expressed in decibels:

$$L_n = L_i + 10 \lg \frac{A}{A_0} \text{ dB} \qquad \ldots (4)$$

where A_0 = 10 m^2.

4 Equipment

The equipment shall comply with the requirements of clause 6.

The standard tapping machine shall meet the requirements given in annex A.

The accuracy of the sound level measurement equipment shall comply with the requirements of accuracy class 0 or 1 defined in IEC 60651 and IEC 60804. The complete measuring system including the microphone shall be adjusted before each measurement to enable absolute values of sound pressure levels to be obtained. If not otherwise stated by the equipment manufacturer, a sound calibrator which complies with the requirements of accuracy class 1 defined in IEC 60942 shall be used. For sound level meters calibrated for measurements in sound fields of progressive plane waves, corrections for the diffuse sound field shall be applied.

The one-third-octave band filters shall comply with the requirements defined in IEC 61260.

The reverberation time measurement equipment shall comply with the requirements defined in ISO 354.

NOTE For pattern evaluation (type testing) and regular verification tests, recommended procedures for sound level meters are given in OIML R58[1] and OIML R88[2]. For the standard tapping machine, similar recommendations are given in annex A.

5 Test arrangement

5.1 Rooms

Laboratory test facilities shall comply with the requirements of ISO 140-1.

5.2 Test specimen

The size of the test specimen is determined by the size of the test opening of the laboratory test facility as defined in ISO 140-1. These sizes are approximately between 10 m^2 and 20 m^2, with the shorter edge length being not less than 2,3 m.

Preferably install the test specimen in a manner as similar as possible to the actual construction, with a careful simulation of normal connections and sealing conditions at the perimeter and at joints within the specimen. The mounting conditions shall be stated in the test report.

The impact sound insulation of solid floors depends on coupling to surrounding structures. In order to describe properly the effect of the mounting, it is recommended to measure and to report the loss factor (see annex D).

The sound radiated by flanking elements should be negligible compared to the sound radiated from the floor under test. This may be checked by the procedures given in annex B.

6 Test procedure and evaluation

6.1 Generation of sound field

The impact sound shall be generated by the tapping machine (see annex A).

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 ribs, beams, etc.) or rough and irregular floor coverings, more positions may be necessary. The hammer connecting line should be orientated at 45° to the direction of the beams or ribs.

The impact sound pressure levels may 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. The measurement period shall be reported. If stable conditions are not reached after 5 min, then the measurements should be carried out over a well-defined measurement period.

When soft coverings are under test, it is necessary that the standard tapping machine fulfils special requirements given in annex A. Advice regarding the mounting of the standard tapping machine on soft floor coverings is given in annex A.

6.2 Measurement of impact sound pressure level

6.2.1 General

Obtain the impact sound pressure level by using a single microphone moved from position to position, or by an array of fixed microphones, or by a continuously moving or oscillating microphone. The sound pressure levels at the different microphone positions shall be averaged on an energy basis [see equations (1) to (3)] for all positions of the tapping machine.

6.2.2 Microphone positions

The following are minimum separating distances:

— 0,7 m between microphone positions;

— 0,7 m between any microphone position and room boundaries or diffusers;

— 1,0 m between any microphone position and the test specimen.

NOTE Greater separating distances should be used wherever possible.

a) Fixed microphone positions

A minimum of four fixed microphone positions shall be used; these shall be evenly distributed within the space permitted for measurement in the room.

b) Moving microphone positions

When using a moving microphone, the sweep radius shall be at least 0,7 m. The plane of the traverse shall be inclined in order to cover a large proportion of the space permitted for measurement. The plane of traverse shall not lie within 10° of any plane of the room (wall, floor, ceiling). The duration of a traverse period shall not be less than 15 s.

6.2.3 Measurement

a) Fixed microphone positions

The **minimum** number of measurements using fixed microphone positions is six, a combination of at least four microphone positions and at least four tapping machine positions shall be used.

EXAMPLE For two microphone and two tapping machine positions, make measurements for all four possible combinations. For the other two microphone and two tapping machine positions, make measurements on a one-to-one basis.

b) Moving microphone positions

The **minimum** number of measurements using a moving microphone is four (e.g. one measurement for each tapping machine position).

When using six or eight tapping machine positions, measurements can be made using either one or two moving microphone positions.

6.2.4 Averaging time

At each individual microphone position, the averaging time shall be at least 6 s at each frequency band with centre frequencies below 400 Hz. For bands of higher centre frequencies, it is permissible to decrease the time to not less than 4 s. Using a moving microphone, the averaging time shall cover a whole number of traverses and shall be not less than 30 s.

6.3 Frequency range of measurements

The sound pressure level 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

Guidance is given in annex C for such additional measurements in the low-frequency bands.

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

The correction term in equation (4) containing the equivalent sound absorption area is evaluated from the reverberation time measured according to ISO 354 and determined using Sabine's formula:

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

where

A is the equivalent absorption area, in square metres;

V is the receiving room volume, in cubic metres;

T is the reverberation time, in seconds.

Following ISO 354, the evaluation of the reverberation time from the decay curve shall begin about 0,1 s after the sound source has been switched off, or from a sound pressure level a few decibels lower than that at the beginning of the decay. The range used shall not be less than 20 dB, and shall not be so large that the observed decay cannot be approximated by a straight line. The bottom of this range shall be at least 10 dB above the background noise level.

The minimum number of decay measurements required for each frequency band is six. At least one loudspeaker position and three microphone positions with two readings in each case shall be used.

Moving microphones which meet the requirements of 6.2.2 may be used but the traverse time shall be not less than 30 s.

6.5 Correction for background noise

Measurements of background noise levels shall be made to ensure that the observations in the receiving room are not affected by extraneous sound such as noise from outside the test room or electrical noise in the receiving system. To check the latter condition, replace the microphone by a dummy microphone. Take care that the airborne noise produced by the tapping machine and transmitted to the receiving room does not influence the impact sound pressure level in the receiving room.

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

$$L = 10\ \lg\left(10^{L_{\mathrm{sb}}/10} - 10^{L_{\mathrm{b}}/10}\right)\ \mathrm{dB} \qquad \text{. . . (6)}$$

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 correction 1,3 dB corresponding to a difference of 6 dB. In that case L_n shall be given in the measurement report so that it clearly appears that the reported L_n values are the limit of measurement [see k) of clause 9].

7 Precision

The measurement procedure shall give satisfactory repeatability. This shall be determined in accordance with the method given in ISO 140-2 and should be verified from time to time, particularly when a change is made in procedure or instrumentation.

NOTE Numerical requirements for repeatability are given in ISO 140-2.

8 Expression of results

For the statement of the impact sound insulation of the test specimen, the values of the normalized impact sound pressure level L_n shall be given at all frequencies of measurement, to one decimal place, 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, using the following dimensions:

— 5 mm for a one-third-octave band,

— 20 mm for 10 dB.

The use of a form in accordance with annex E is preferred. This being a short version of the test report, state all information of importance regarding the test object, the test procedure and the test results.

If results of normalized impact sound pressure level evaluations are also needed in octave bands, these values shall be calculated from the three one-third-octave band values in each octave band using equation (7):

$$L_{n,oct} = 10 \lg \left(\sum_{j=1}^{3} 10^{L_{n,1/3oct,j}/10} \right) \text{dB} \qquad \text{. . . (7)}$$

If the test procedure is repeated, the arithmetic mean of all measurement results at each frequency band shall be calculated.

9 Test report

The test report shall state:

a) reference to this part of ISO 140;

b) name and address of the testing laboratory;

c) manufacturer's name and product identification;

d) name and address of the organization or person who ordered the test (client);

e) date of test;

f) description of the test specimen with sectional drawing if adequate and mounting conditions, including size, thickness, mass per unit area, curing time and conditions of components; a statement indicating who mounted the test object (test institute or manufacturer);

g) volume of the receiving room;

h) air temperature and humidity in the measuring rooms (if relevant);

i) normalized impact sound pressure level of test specimen as a function of frequency;

j) brief description of details of procedure and equipment;

k) indications of results which are to be taken as limits of measurement; these shall be given as $L_n \leq ...$ dB; this shall be applied if the sound pressure level in any band is not measurable because of background noise (acoustic or electrical, see 6.5);

l) the flanking transmission [if measured (see annex B)] in the same form as L_n; it should be stated as clearly as possible which part or parts of the transmitted sound are included in the flanking transmission measurement;

m) total loss factor η_{total} [if measured (see annex D)] at all frequencies of measurement in tabular form and/or in the form of a curve.

For the evaluation of a single-number rating from the curve $L_n(f)$, see ISO 717-2. It shall be clearly stated that the evaluation has been based on a result obtained by a laboratory method.

Annex A
(normative)

Requirements for the standard tapping machine

The equipment shall be suitable for meeting the requirements of clause 6.

The 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 which 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 has to 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 must 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 the 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 spheremeter 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.

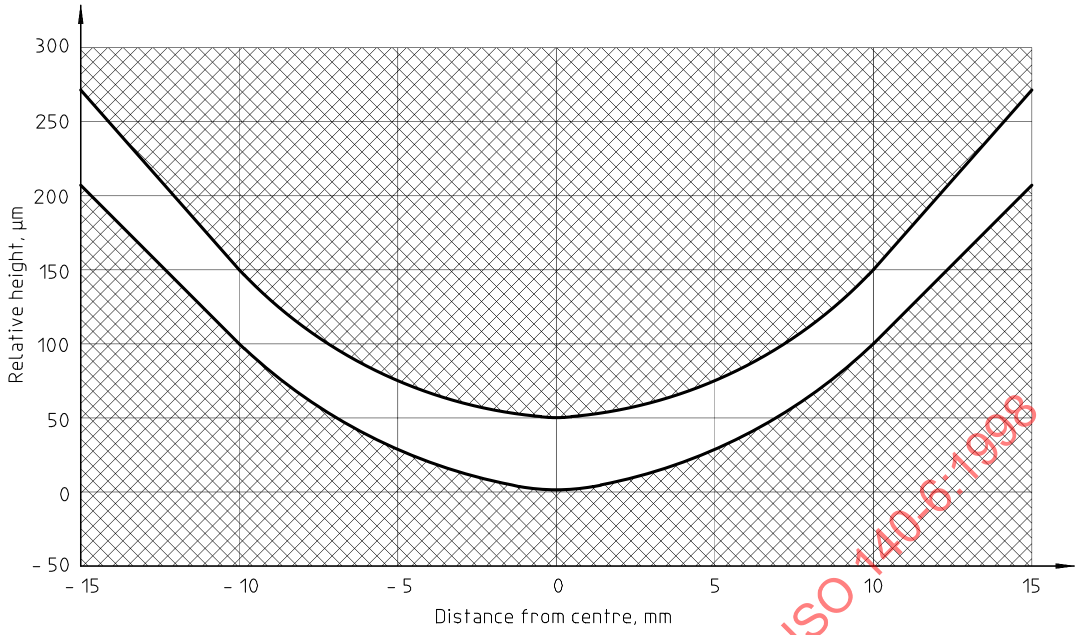
The time between impact and lift of the hammer shall be less than 80 ms.

For standard tapping machines which 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.

If the test surface is covered with an extremely soft covering or if the surface is very uneven so that the hammers are not able to fall down the requisite 40 mm to the surface on which the supports rest, pads may be used under the supports to ensure the correct falling height of 40 mm.

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



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

Some of the parameters only need to be measured once unless the tapping machine has been modified. 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 the time between impacts shall be verified regularly.

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

Annex B
(informative)

Measurement of flanking transmission

If the flanking transmission has to be investigated, this may be done by measuring the average surface velocity levels of the specimen and the flanking surfaces in the receiving room. The average surface vibration velocity level, L_v, of a specimen in decibels is given by

$$L_v = 10 \lg \left(\frac{v_1^2 + v_2^2 + \ldots + v_n^2}{n v_0^2} \right) \text{dB} \qquad \ldots \text{(B.1)}$$

where

$v_1, v_2, \ldots, v_n$ are the r.m.s. normal surface vibration velocities at n different positions on the specimen;

v_0 is the reference velocity[1] ($v_0 = 10^{-9}$ m/s).

NOTE In building acoustics, the reference velocity of 5×10^{-8} m/s is also in use. Therefore, the reference velocity used in equation (B.1) should always be stated.

The vibration transducer used should be well attached to the surface, and its mass impedance should be sufficiently low compared with the point impedance of the surface.

If the critical frequency of the specimen or of the flanking objects 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

$$W_k = \rho c S_k \overline{v_k^2} \sigma_k \qquad \ldots \text{(B.2)}$$

where

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

σ_k is the radiation efficiency, a pure figure of about 1 above the critical frequency;

ρc is the characteristic impedance of air.

From the average surface velocity level L_v, the average sound pressure level in the receiving room due to the radiation of the k-th flanking element may be calculated according to the equation

$$L_k = L_{vk} + 10 \lg \frac{4 S_k}{A} \text{dB} - C \qquad \ldots \text{(B.3)}$$

with $C = 34$ dB if $v_0 = 10^{-9}$ m/s is used;

$C = 0$ dB if $v_0 = 5 \times 10^{-8}$ m/s is used.

The resulting sound pressure level of all flanking constructions is

$$L_{Df} = 10 \lg \left(\sum_k 10^{L_k/10} \right) \text{dB} \qquad \ldots \text{(B.4)}$$

1) Taken from ISO 1683.

Annex C
(informative)

Guidance for measurements in low frequency bands

C.1 General

In low-frequency bands (lower than about 400 Hz in general and especially lower than 100 Hz), no diffuse-field conditions in the test rooms can be expected, especially when room volumes of 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 small number of room modes in the bands are the cause of standing wave structures that are found in the whole room space.

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 receiving room and the special requirements that the room has to meet.

Rooms with small volumes and unfavourable dimensions are not suitable 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 sufficient space to position the microphones according to the requirements.

C.2 Minimum distances

A strong sound pressure level increase is measured towards the room boundaries from a distance of about a quarter of a wavelength. The minimum separating distances (see 6.2.1) have to be increased linearly, being doubled for measurements in the 50 Hz band. For the distance between the microphone positions and the room boundaries, about 1,2 m should be the ultimate limit.

C.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 uniformly. 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.

C.4 Averaging time

Due to the smaller absolute filter bandwidth and low modal overlap, the averaging times should be increased to not less than 15 s for measurements in the 50 Hz band (about three times compared to the requirements for measurements at 100 Hz). When using a moving microphone, the averaging time should not be less than 60 s.

C.5 Reverberation time

At very low frequencies, test rooms with hard surfaces tend to have long reverberation times. This should be avoided in order to reduce the dominance of single room modes by improving the modal overlap. The absorption in the room should be well distributed. The use of plasterboard linings on mineral wool layers on walls and ceiling and a floating floor is recommended.

Annex D
(informative)

Measurement of total loss factor

D.1 General

A physical system which exchanges energy with other systems through weak coupling is considered. E is the vibrational energy of the system in a frequency band ($f \pm \Delta f$) under steady-state conditions. Through external forces, the energy ΔE is injected into the system in the same frequency band and during a period corresponding to frequency f, to keep E constant. Then the total loss factor η_{total} is given by

$$\eta_{total} = \frac{\Delta E}{2\pi E} \qquad \text{. . . (D.1)}$$

For example, the system may be a wall, or a group of strongly coupled walls of approximately the same surface density.

The other systems may be a volume of air, another wall or partition of different mass, coupled or attached to the system through resilient connections. The total loss factor includes the internal losses, the edge losses and the radiation losses.

D.2 Measurements

The relation between η_{total} and the reverberation time T_R of the system, when excited by an impulse force is given by

$$\eta_{total} = \frac{2{,}2}{f\,T_R} \qquad \text{. . . (D.2)}$$

The reverberation time is estimated by measuring the velocity or acceleration of different points in the system. It is suggested that the reverberation time should be calculated from the decay curve between 5 dB and 20 dB below the maximum level. On a typical wall construction (10 m^2 to 20 m^2), the averaged value of 12 decay curves should be taken, typically two measurement points times three excitation points times two decays per point.

The excitation may be obtained by the impact of a shaker or a hammer covered with a rubber pad. The mass of the hammer should be approximately that of 100 cm^2 of the excited wall. The reverberation time is often as small as 20 ms, so that the usual data-processing procedure for airborne reverberation time measurements cannot be applied. In order to avoid the influence of the filters and the r.m.s. detector on the decay curves, the following method may be used.

Record the decay curve on a tape recorder or a transient memory, and replay it reversed, if suitable at a slower speed. Take measurements using transposed filters. The product of the filter bandwidth B and the measured reverberation time should exceed 16 for forward analysis and 4 when time-reversed analysis is used. The r.m.s. detector should have a short time constant. The equivalent reverberation time T_{rms} of a r.m.s. detector of time constant τ is T_R = 13,8 τ. It is recommended that T_{rms} should be less than half the measured reverberation time using forward analysis. When time-reversed analysis is used, T_{rms} may be up to four times the measured reverberation time.