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ISO 140-7

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

Part 7:
Field measurements of impact sound insulation of floors

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

Partie 7: Mesurage in situ de la transmission des bruits de choc par les planchers

Reference number
ISO 140-7:1998(E)

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 140-7 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*.

This second edition cancels and replaces the first edition (ISO 140-7:1978), 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*

Annexes A and B form an integral part of this part of ISO 140. Annexes C to E are for information only.

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

Part 7:
Field measurements of impact sound insulation of floors

1 Scope

This part of ISO 140 specifies field methods for measuring the impact sound insulation properties of building 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 compare the apparent impact sound insulation of floors with specified requirements.

NOTE 1 Laboratory measurements of impact sound insulation of floors are dealt with in ISO 140-6.

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

ISO 140-3:1995, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 3: Laboratory measurements of airborne sound insulation of building elements.*

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 purposes of this part of ISO 140, the definitions given in ISO 140-3 and 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.

In practice, usually the sound pressure levels L_j are measured. In this case L is determined by

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

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 equivalent absorption area A_0; it is expressed in decibels:

$$L'_n = L_i + 10 \lg \frac{A}{A_0} \text{ dB} \qquad \ldots (2)$$

with $A_0 = 10 \text{ m}^2$.

3.4 standardized impact sound pressure level, L'_{nT}: Impact sound pressure level L_i reduced by a correction term which is given in decibels, being ten times the logarithm to the base 10 of the ratio of the measured reverberation time T of the receiving room to the reference reverberation time T_0; it is expressed in decibels:

$$L'_{nT} = L_i - 10 \lg \frac{T}{T_0} \text{ dB} \qquad \ldots (3)$$

NOTE 1 For dwellings T_0 equals 0,5 s.

NOTE 2 The standardizing of the impact sound pressure level to a reverberation time of 0,5 s takes into account that in dwellings the reverberation time has been found to be (nearly independent of the volume and of the frequency) equal to 0,5 s.

NOTE 3 The standardizing of the impact sound pressure level to the reverberation time of T_0 = 0,5 s is equivalent to standardizing the impact sound pressure level to a reference absorption area of

$$A_0 = 0{,}32V$$

where

A_0 is the reference absorption area, in square metres;

V Is the volume of the receiving room, in cubic metres.

3.5 reduction of impact sound pressure level, $\Delta L'$: Difference, in decibels, between the average sound pressure levels in the receiving room before and after the installation of, for example, a floor covering.

NOTE See ISO 140-8 for further information.

4 Equipment

The equipment shall comply with the requirements of clause 5.

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. If not otherwise stated by the equipment manufacturer, the complete measuring system including the microphone shall be adjusted before each measurement using a sound calibrator which complies with the requirements of accuracy class 1 defined in IEC 60942. For sound level meters calibrated for measurements in sound fields of progressive plane waves, corrections for the diffuse sound field shall be applied.

The 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 R 58[1] and OIML R 88[2].

5 Test procedure and evaluation

5.1 General

The field measurements of impact sound insulation of floors shall be made in one-third-octave bands unless octave band measurements have been agreed upon. When the results from octave band measurements are converted to single-number quantities, these results are not directly comparable with those from one-third-octave band measurements. The procedure for octave band measurements is specified in annex B.

5.2 Generation of sound field

The impact sound shall be generated by the tapping machine (see clause 4).

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.), 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. 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.

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

5.3 Measurement of impact sound pressure level

5.3.1 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 equation (1)] for all positions of the tapping machine.

5.3.2 Microphone positions

The following are minimum separating distances:

— 0,7 m between microphone positions;

— 0,5 m between any microphone position and room boundaries or diffusers;

— 1,0 m between any microphone position and the upper floor being excited by the tapping machine.

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.

5.3.3 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.

5.3.4 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. In order to avoid alterations of the surface by long tapping periods, moving microphones should be used in conjunction with parallel real-time measurements in the filter bands.

5.4 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		

In order to obtain additional information and to obtain results comparable to that of laboratory measurements according to ISO 140-6, it is recommended to enlarge the frequency range of the measurements by one-third-octave filter bands with the following centre frequencies, in hertz:

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.

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

The correction term in equation (2) containing the equivalent sound absorption area is evaluated from the reverberation time measured according to ISO 354 and determined using Sabine's formula:

$$A = \frac{0{,}16\,V}{T} \qquad \ldots (4)$$

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, begin the evaluation of the reverberation time from the decay curve 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. Use a range neither less than 20 dB, nor 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 5.3.2 may be used but the traverse time shall be not less than 30 s.

5.6 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 10 dB) below the level of signal and background noise combined. If the difference in levels is smaller than 10 dB but greater than 6 dB, calculate corrections to the signal level according to equation (5):

$$L = 10 \lg \left(10^{L_{sb}/10} - 10^{L_b/10}\right) \text{ dB} \qquad \ldots (5)$$

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 indicate L'_n values in the measurement report so that it is clear that the reported values are the limit of measurement [see i) of clause 8].

6 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 the procedure or instrumentation.

7 Expression of results

For the statement of the impact sound insulation between rooms in buildings, the values of the normalized or standardized impact sound pressure level L'_n or L'_{nT} 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 level 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 forms in accordance with annex D is preferred. These being a short version of the test report, state all information of importance regarding the test object, the test procedure and the test results.

When calculating values of L'_n or L'_{nT} in octave bands, from the values in one-third-octave bands, the following equations shall be used:

$$L'_{n,oct} = 10 \lg \left(\sum_{j=1}^{3} 10^{L'_{n,1/3\,oct,j}/10} \right) \text{ dB} \qquad \ldots (6)$$

$$L'_{nT,oct} = 10 \lg \left(\sum_{j=1}^{3} 10^{L'_{nT,1/3\,oct,j}/10} \right) \text{ dB} \qquad \ldots (7)$$

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

8 Test report

The test report shall state:

a) reference to this part of ISO 140;

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

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

d) date of test;

e) description and identification of the building construction and test arrangement;

f) volume of the receiving room;

g) either the normalized impact sound pressure level L'_n or the standardized impact sound pressure level L'_{nT} as a function of frequency, whichever is appropriate;

h) brief description of details of procedure and equipment;

i) indications of results which are to be taken as limits of measurement. They shall be given as L'_n or $L'_{nT} \leq$ ... dB; this shall be applied if the relevant sound pressure level in any band is not measurable on account of background noise (acoustic or electrical, see 5.6);

j) the flanking transmission (if measured) 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.

For the evaluation of single-number ratings from the curves $L'_n(f)$ or $L'_{nT}(f)$ see ISO 717-2. It shall be clearly stated that the evaluation has been based on a result obtained by a field method.

Annex A
(normative)

Requirements for the standard tapping machine

The equipment shall be suitable for meeting the requirements of clause 5.

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 0,033 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.

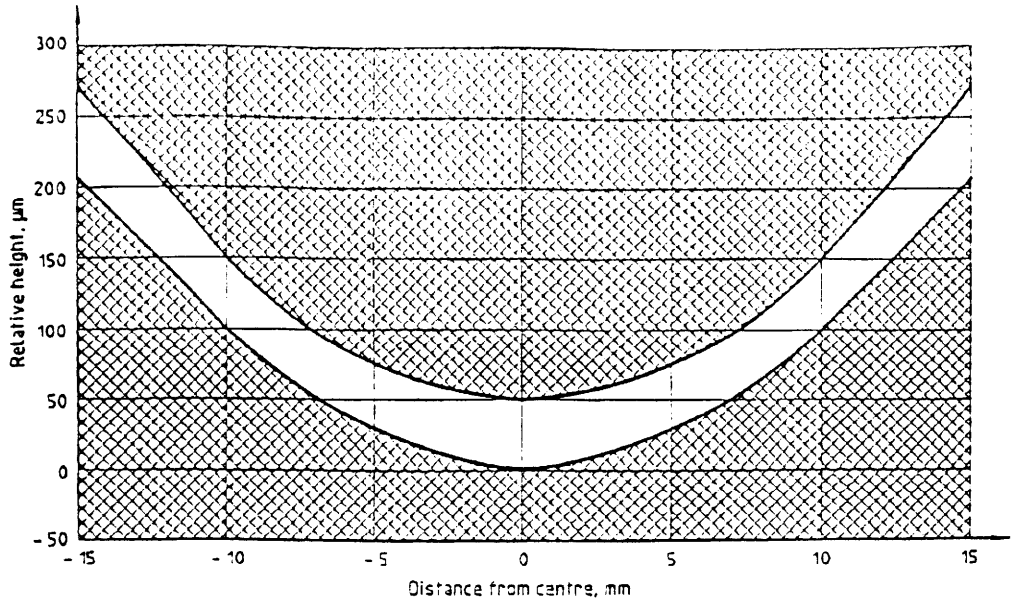
The time between impact and lift of the hammer shall be less than 80 ms.

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 verifications on 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 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
(normative)

Procedures for the measurement of sound insulation in octave bands

B.1 General

For the field measurements of impact sound insulation between rooms, the procedure for the measurement in one-third-octave bands is specified in this standard. However, if measurements in octave bands have to be performed, the procedure given in this annex shall be applied.

B.2 Measurement of impact sound pressure level

Details of measurement procedures such as microphone positions or microphone traverse paths, averaging time and spatial averaging procedures are the same as those specified in 5.4.

B.3 Frequency range of interest

The sound pressure level shall be measured using octave band filters having at least the following centre frequencies, in hertz:

125 250 500 1 000 2 000

It is recommended to enlarge the frequency range of the measurements by the octave filter band of 4 000 Hz in order to obtain additional information and to obtain results comparable to that of laboratory measurements according to ISO 140-6. If additional information in the low-frequency range is required, then an octave band filter with the centre frequency of 63 Hz should be used. When such additional measurements in the low-frequency band are performed, the guidance given in annex C should be followed.

B.4 Measurement of reverberation time and evaluation of the equivalent sound absorption area

Follow the procedure given in 5.5.

B.5 Correction for background noise

Follow the procedure given in 5.6.

B.6 Precision

Follow the requirements given in clause 6.

B.7 Expression of results

For the statement of the impact sound insulation of the separating elements, the values of the normalized or standardized impact sound pressure level 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:

— 15 mm for an octave band,

— 20 mm for 10 dB.

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

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 only 50 m^3 or even less 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 sampling of the sound field in the receiving room and the special requirements that the rooms have to meet.

In rooms with small volumes and unfavourable dimensions, it is not always possible to obtain reliable results of 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 5.3.2) 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.

Annex D
(informative)

Forms for the expression of results

This annex gives examples of forms for the expression of results for the field measurements of impact sound insulation of floors (for one-third-octave bands and for octave bands).

The curves of reference values shown in the forms are taken from ISO 717-2. The latest version of that standard is applied. The reference curves should be supplemented or at least replaced by the shifted reference curves according to the procedure described in ISO 717-2.

Normalized impact sound pressure levels according to ISO 140-7
Field measurements of impact sound insulation of floors

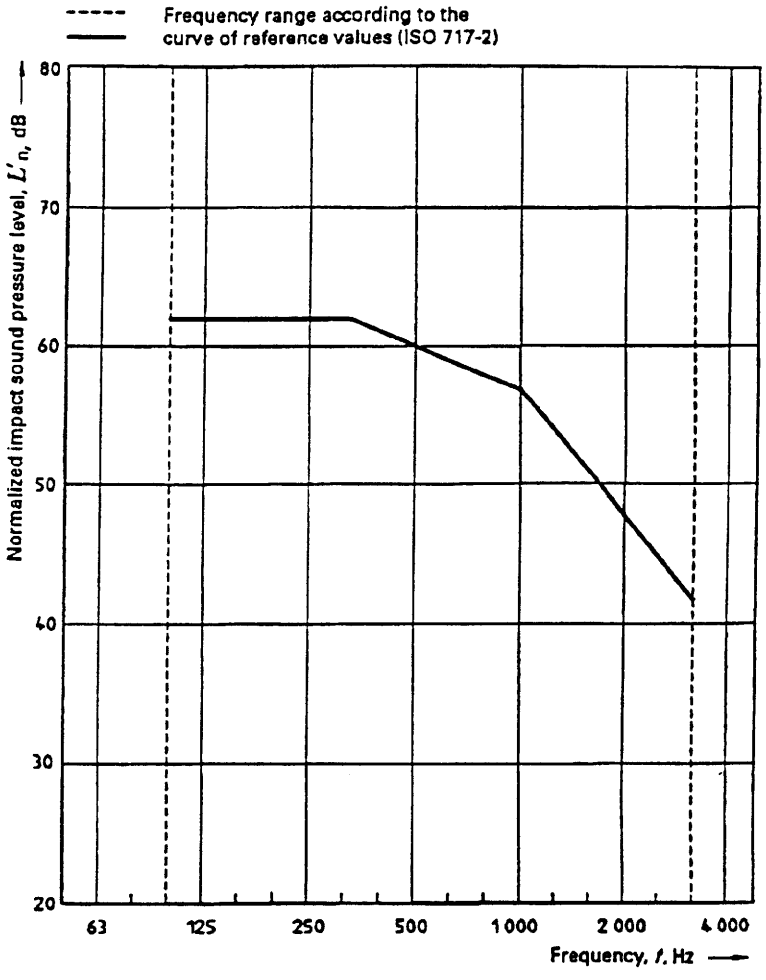
Client :

Date of test :

Description and identification of the building construction and test arrangement:

Receiving room volume : m³

Frequency f Hz	L'_n (one-third octave) 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 according to ISO 717-2

$L'_{n,w}(C_I)$ = ( ) dB; $C_{I,50\text{-}2500}$ = dB

Evaluation based on field measurement results obtained in one-third-octave bands by an engineering method.

No. of test report :

Name of test institute :

Date :

Signature :

Annex E
(informative)

Bibliography

[1] 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.*

[2] ISO 140-6:1998, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 6: Laboratory measurements of impact sound insulation of floors.*

[3] ISO 140-8:1997, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 8: Laboratory measurements of the reduction of transmitted impact noise by floor coverings on a solid standard floor.*

[4] OIML R 58:1984, *Sound level meters*[1)].

[5] OIML R 88:1989, *Integrating-averaging sound level meters.*[1)]

1) These documents may be obtained from: Organisation internationale de métrologie légale, 11 rue Turgot, 75009 Paris, France.