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

Part 4:
Field measurements of airborne sound insulation between rooms

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

Partie 4: Mesurage in situ de l'isolement aux bruits aériens entre les pièces

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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 140-4 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*.

This second edition cancels and replaces the first edition (ISO 140-4:1978) 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 F are for information only.

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

Part 4:
Field measurements of airborne sound insulation between rooms

1 Scope

This part of ISO 140 specifies field methods for measuring the airborne sound insulation properties of interior walls, floors and doors between two rooms under diffuse sound field conditions in both rooms, and for determining the protection afforded to the occupants of the building.

The methods give values for airborne sound insulation which are frequency dependent. They can be converted into a single number, characterizing the acoustic performance, by application of ISO 717-1.

The results obtained can be used to compare sound insulation between rooms and to compare actual sound insulation with specified requirements.

NOTE 1 Laboratory measurements of airborne sound insulation of building elements are dealt with in ISO 140-3.

NOTE 2 Field measurements of airborne sound insulation of façade elements and façades are dealt with in ISO 140-5.

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 717-1:1996, *Acoustics — Rating of sound insulation in buildings and of building elements — Part 1: Airborne 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 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

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

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

3.2 level difference, D**:** Difference, in decibels, in the space and time average sound pressure levels produced in two rooms by one or more sound sources in one of them:

$$D = L_1 - L_2 \qquad \text{. . . (2)}$$

where

L_1 is the average sound pressure level in the source room;

L_2 is the average sound pressure level in the receiving room.

3.3 normalized level difference, D_n**:** Level difference, in decibels, corresponding to the reference absorption area in the receiving room:

$$D_n = D - 10 \lg \frac{A}{A_0} \text{ dB} \qquad \text{. . . (3)}$$

where

D is the level difference, in decibels;

A is the equivalent sound absorption area of the receiving room, in square metres;

A_0 is the reference absorption area, in square metres (for rooms in dwellings or rooms of comparable size: A_0 = 10 m²).

3.4 standardized level difference, D_{nT}**:** Level difference, in decibels, corresponding to a reference value of the reverberation time in the receiving room:

$$D_{nT} = D + 10 \lg \frac{T}{T_0} \text{ dB} \qquad \text{. . . (4)}$$

where

D is the level difference;

T is the reverberation time in the receiving room;

T_0 is the reference reverberation time; for dwellings, T_0 = 0,5 s.

NOTE 1 The standardizing of the level difference to a reverberation time of 0,5 s takes into account that in dwellings with furniture the reverberation time has been found to be reasonably independent of the volume and of frequency and to be approximately equal to 0,5 s. With this standardizing, D_{nT} is dependent on the direction of the sound transmission if the two rooms have different volumes.

NOTE 2 The standardizing of the level difference to the reverberation time in the receiving room of T_0 = 0,5 s is equivalent to standardizing the level difference with respect to a reference absorption area of

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

where

A_0 is the reference absorption area, in square metres;

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

3.5 apparent sound reduction index R': Ten times the logarithm to the base 10 of the ratio of the sound power W_1 which is incident on a partition under test to the total sound power transmitted into the receiving room if, in addition to the sound power W_2 transmitted through the separating element, the sound power W_3, transmitted through flanking elements or by other components, is significant; it is expressed in decibels:

$$R' = 10 \lg \frac{W_1}{W_2 + W_3}\ \text{dB} \qquad \text{. . . (5)}$$

NOTE 1 Explanations of W_3 are given in annex C.

NOTE 2 The expression "apparent sound transmission loss" is also in use in English-speaking countries. It is equivalent to "apparent sound reduction index".

NOTE 3 In general, the sound power transmitted into the receiving room consists of the sum of several components. Also in this case, under the assumption that there are sufficiently diffuse sound fields in the two rooms, the apparent sound reduction index in this part of ISO 140 is evaluated from

$$R' = D + 10 \lg \frac{S}{A}\ \text{dB} \qquad \text{. . . (6)}$$

where

D is the level difference;

S is the area of the separating element;

A is the equivalent sound absorption area in the receiving room.

In the case of determination of the sound reduction of a door, S is the area of the free opening in which the door including the frame is mounted. It has to be proved that the sound transmission through the rest of the surrounding wall is negligible.

In the case of staggered or stepped rooms, S is that part of the area of the partition common to both rooms. If the common area is less than 10 m^2, indicate this in the test report. S is then calculated by max.(S, V/7,5), where V is the volume, in cubic metres, of the receiving room (which is the smaller room in this case).

In the case that no common area exists, the normalized level difference D_n is determined.

NOTE 4 In general, comparison between results from field measurements and those from laboratory measurements should only be done where the common area S is approximately 10 m^2.

NOTE 5 In the apparent sound reduction index, the sound power transmitted into the receiving room is related to the sound power which is incident on the common partition irrespective of actual conditions of transmission. The apparent sound reduction index is independent of the measuring direction between the rooms if the sound fields are diffuse in both rooms.

4 Equipment

The equipment shall comply with the requirements of clause 6.

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.

Requirements for the sound source are given in 6.2 and annex A.

NOTE For pattern evaluation (type testing) and regular verification tests, recommended procedures for sound level meters are given in OIML R58[3] and OIML R88[4].

5 Test arrangement

Measurements between empty rooms with identical shape and equal dimensions should preferably be made with diffusers in each room (e.g. pieces of furniture, building boards). The area of a diffuser should be at least 1,0 m^2; three or four objects will be normally sufficient.

NOTE Guidelines (e.g. in the form of a technical report) for performing measurements in special measurement situations are under consideration.

6 Test procedure and evaluation

6.1 General

The field measurements of airborne sound insulation shall be made in one-third-octave bands unless octave band measurements have been agreed upon. The procedure for octave band measurements is specified in annex B. 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.

6.2 Generation of sound field in the source room

The sound generated in the source room shall be steady and have a continuous spectrum in the frequency range considered. If filters are used, use those with a bandwidth of at least one-third octave. If broad-band noise is used, the spectrum may be shaped to ensure an adequate signal-to-noise ratio at high frequencies in the receiving room (white noise is recommended). In either case, the sound spectrum in the source room shall not have differences in level greater than 6 dB between adjacent one-third-octave bands.

The sound power should be sufficiently high for the sound pressure level in the receiving room to be at least 10 dB higher than the background noise level in any frequency band. If this is not fulfilled, corrections shall be applied as shown in 6.6.

If the sound source enclosure contains more than one loudspeaker operating simultaneously, the loudspeakers shall be driven in phase or it shall be assured in other ways that the radiation is uniform and omnidirectional, as specified in A.1.3. It is permissible to use multiple sound sources simultaneously, provided that they are of the same type and are driven at the same level by similar, but uncorrelated, signals. When using a single sound source, it shall be operated in at least two positions. If the rooms are of different volumes, the larger one should be chosen as source room when the standardized level difference is to be evaluated and no contradictory procedure is agreed upon. In order to evaluate the apparent sound reduction index measurement, results from one measurement direction only or from both directions may be used. That means the loudspeaker positions shall be in the same room or the measurements shall be repeated in the opposite direction by changing source and receiving room with one or more source positions in each room.

Place the loudspeaker enclosure so as to give a sound field as diffuse as possible and at such a distance from the separating element and the flanking elements influencing the sound transmission that the direct radiation upon them is not dominant. The sound fields in the rooms depend strongly on the type and on the position of the sound source. Qualification of the loudspeakers and of the loudspeaker positions shall be performed using the procedures given in annex A.

6.3 Measurement of average sound pressure level

6.3.1 General

Obtain the average 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 sound source positions.

6.3.2 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 sound source.

NOTE Greater separating distances should be used wherever possible.

a) Fixed microphone positions

A minimum of five 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.

6.3.3 Measurement

a) Using a single sound source

The **minimum** number of measurements using fixed microphone positions is ten (e.g. one measurement at each microphone position corresponding to each loudspeaker position).

The **minimum** number of measurements using a moving microphone is two (e.g. one measurement with each loudspeaker position).

b) Using a multiple sound source operating simultaneously

The **minimum** number of measurements using fixed microphone positions is five.

The **minimum** number of measurements using a moving microphone is one.

6.3.4 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.

6.4 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 140-3, 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 D for such additional measurements in the low-frequency bands.

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

The correction term of equation (6) containing the equivalent sound absorption area is evaluated from the reverberation time measured in accordance with ISO 354 and determined using Sabine's formula:

$$A = \frac{0,16\,V}{T} \qquad \ldots (7)$$

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 the receiving room, 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 6.3.2 may be used but the traverse time shall be not less than 30 s.

6.6 Correction for background noise

Measure background noise levels to ensure that the observations in the receiving room are not affected by 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.

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 the following equation:

$$L = 10 \lg \left(10^{L_{sb}/10} - 10^{L_b/10} \right) \text{ dB} \qquad \text{. . . (8)}$$

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 D_n, D_{nT} or R' in the measurement report so that it is clear that the reported values are the limit of measurement [see j) 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 the procedure or instrumentation.

8 Expression of results

For the statement of the airborne sound insulation between rooms, the values of the normalized level difference D_n, the standardized level difference D_{nT} or the apparent sound reduction index R' 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 forms in accordance with annex E is preferred. 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 the values of D_n, D_{nT} or R' in octave bands from the values in one-third-octave bands, the following equations shall be used:

$$D_{n,oct} = -10 \lg \left(\sum_{j=1}^{3} \frac{10^{-D_{n,1/3\,oct,j}/10}}{3} \right) \text{dB} \qquad \text{. . . (9)}$$

$$D_{nT,\text{oct}} = -10 \lg \left(\sum_{j=1}^{3} \frac{10^{-D_{nT,1/3\,\text{oct},j}/10}}{3} \right) \text{dB} \qquad \text{. . . (10)}$$

$$R'_{\text{oct}} = -10 \lg \left(\sum_{j=1}^{3} \frac{10^{-R'_{1/3\,\text{oct},j}/10}}{3} \right) \text{dB} \qquad \text{. . . (11)}$$

If the test procedure for R' is repeated either in the same or in the opposite measurement direction, 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 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) volumes of both rooms;

g) either the normalized level difference D_n or the standardized level difference D_{nT} between the rooms or the apparent sound reduction index R' of the separating element as a function of frequency, whichever is appropriate;

h) the area S used for evaluation of R';

i) brief description of details of procedure and equipment;

j) indications of results which are to be taken as limits of measurement. They shall be given as D_n, D_{nT} or $R' \geq$...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 6.6);

k) the flanking transmission [if measured (see annex C)] in the same form as R'. It should be stated as clearly as possible which part or parts of the transmitted sound power are included in the flanking transmission measurement.

For the evaluation of single-number ratings from the curves $D_n(f)$, $D_{nT}(f)$ and $R'(f)$, see ISO 717-1. It shall be clearly stated that the evaluation has been based on a result obtained by a field method.

Annex A
(normative)

Qualification and positioning of the sound source

A.1 Qualification procedures for loudspeakers and for loudspeaker positions relative to microphone positions

A.1.1 General

The objective of these requirements is to make the sound field in the source room which is sampled by the microphones as diffuse as possible. The positions and the directivity of the source shall permit microphone positions to be outside the direct field of the source and shall ensure that the direct radiation from the source is not dominant on the surface of the walls, floors and ceilings which contribute to the sound transmission.

Requirements for radiation characteristics of the sound source depend on the dimensions of the source room. It is essential that the requirement for separating distances given in 6.3.2 is fulfilled if a source is used which meets the requirements for uniform omnidirectional radiation given in A.1.3.

A.1.2 Loudspeaker positions with regard to microphone positions

Ensure that the microphone positions are outside the direct sound field of the source. Each fixed microphone position shall lie outside the region in which levels decrease significantly with distance from the source.

When using a source with omnidirectional radiation, the distance to a microphone shall be not less than 1 m (see 6.3.2).

For a moving microphone, no significant level increase shall occur when the path comes close to the source.

A.1.3 Test procedure for loudspeaker radiation directivity

At all source positions in the free room space, loudspeakers should be used with the speaker units mounted in a closed cabinet. All speaker units in the same cabinet shall radiate in phase.

Mounting loudspeakers on the surfaces of a polyhedron, preferably a dodecahedron, gives an adequate approximation of uniform omnidirectional radiation. Omnidirectional radiation into the room is also achievable with a hemisphere polyhedron loudspeaker (mounted directly on the floor). Carry out vertical measurements in this case in the direction from the lower room to the upper room.

For a test of the directional radiation of a source, measure the sound pressure levels around the source at a distance of about 1,5 m in a free field. The source shall be driven with a noise signal, and measurements made in one-third-octave bands. Measure the level difference between the energetic mean value for the arc of 360° (L_{360}) and the "gliding" mean values of all arcs of 30° ($L_{30,i}$).

The directivity indices are

$$\mathrm{DI}_i = L_{360} - L_{30,i}$$

Uniform omnidirectional radiation can be assumed if the DI values are within the limits of ±2 dB in the frequency range from 100 Hz to 630 Hz. In the range from 630 Hz to 1 000 Hz, the limits increase linearly from ±2 dB to ± 8 dB. They are ±8 dB for frequencies of 1 000 Hz to 5 000 Hz.

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

A.2 Guidance on the selection of optimum source positions

The suitability of source positions also depends on the radiation characteristic of the loudspeaker as well as on the microphone positions (or the microphone path in the case of a moving microphone).

The distance between different loudspeaker positions shall be not less than 0,7 m.

At least two positions shall be not less than 1,4 m apart.

The distance between the room boundaries and the source centre shall be not less than 0,5 m. Small irregularities of the room boundaries may be neglected.

Different loudspeaker positions shall not be located within the same planes parallel to the room boundaries.

Deviating from the above-mentioned requirements concerning the distance between the room boundaries and the source, especially in small rooms it is often of advantage for the practical execution of the measurements to use loudspeaker positions in the corners of the source room. Take special care with regard to possible influence on the flanking transmission and with regard to unwanted increase of level fluctuations in the source room.

Annex B
(normative)

Procedures for the measurement of sound insulation in octave bands

B.1 General

For the field measurements of airborne sound insulation between rooms, the procedure for the measurement in one-third-octave bands is specified in this part of ISO 140. However, if measurements in octave bands have to be performed, this annex shall be applied.

B.2 Generation of sound field in the source room

The sound generated in the source room should be steady and should have a smooth spectrum. This shall be checked by measurements of the sound power levels of the sound source in one-third-octave bands in a reverberation room. The differences between the sound power levels in the one-third-octave bands belonging to an octave band shall not be greater than 6 dB in the 125 Hz octave band, 5 dB in the 250 Hz band, and 4 dB in bands of higher centre frequencies.

Filters with a bandwidth of at least one octave shall be used. When using broad-band noise, the spectrum of the noise source may be modified to ensure an adequate signal-to-noise ratio at high frequencies in the receiving room.

Other specifications on the sound source are the same with those stated in 6.2.

B.3 Measurement of average sound pressure level

Details of measurement procedures such as microphone positions or microphone traverse paths, averaging time and spatial averaging procedures are the same with those specified in 6.3.

B.4 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 4 000 Hz octave filter band in order to obtain additional information and to obtain results comparable to that of laboratory measurements according to ISO 140-3. If additional information in the low frequency range is required, then an octave band filter with a centre frequency of 63 Hz should be used. When such additional measurements in the low frequency band are performed, the guidance given in annex D should be followed.

B.5 Measurement of reverberation time and evaluation of the equivalent sound absorption area

Follow the procedure given in 6.5.

B.6 Correction for background noise

Follow the procedure given in 6.6.

B.7 Precision

Follow the requirements given in clause 7.

B.8 Expression of results

For the statement of the airborne sound insulation between rooms, the values of the normalized level difference D_n, the standardized level difference D_{nT}, or the apparent sound reduction index R', 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, the following dimensions using:

— 15 mm for an octave band;

— 20 mm for 10 dB.

If the test procedure for R' is repeated either in the same or in the opposite measurement direction, the arithmetic mean of all measurement results at each frequency band shall be calculated.

Annex C
(informative)

Measurement of flanking transmission

The sound power transmitted into the receiving room can be assumed to consist of the sum of the following components:

W_{Dd} power which has entered the partition directly and is radiated from it directly;

W_{Df} power which has entered the partition directly but is radiated from flanking constructions;

W_{Fd} power which has entered flanking constructions and is radiated from the partition directly;

W_{Ff} power which has entered flanking constructions and is radiated from flanking constructions;

W_{leak} power which has been transmitted (as airborne sound) through leaks, ventilation ducts, etc.

If the flanking transmission has to be investigated, this may be done in either of the following ways.

a) By covering the separating element on both sides with additional flexible layers, for example 13 mm gypsum board on a separate frame at a distance which gives a resonance frequency of the system of layer and airspace well below the frequency range of interest. The airspace should contain sound-absorbing material. With this measurement W_{Dd}, W_{Df} and W_{Fd} are suppressed, and the measured apparent reduction index is determined by W_{Ff}. Additional flexible layers, covering particular flanking surfaces, may permit identification of the major flanking paths.

b) 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 the specimen is given by:

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

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

NOTE 1 In building acoustics, the reference velocity of 5×10^{-8} m/s is also in use. Therefore, the reference velocity used in equation (C.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 (lowest coincidence frequency at sound incidence of 90°) 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 in the receiving room may be estimated by

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

1) Taken from ISO 1683.

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 figure of about 1 above the critical frequency;

ρc is the characteristic impedance of air.

If, for instance, the power radiated from the flanking constructions is determined in this way, the measurement can be used for the calculation of the apparent sound reduction index, in decibels, as follows:

$$R'_{\mathrm{Df+Ff}} = 10\,\lg\left(\frac{W_1}{W_{\mathrm{Df}} + W_{\mathrm{Ff}}}\right)\ \mathrm{dB} \qquad \text{. . . (C.3)}$$

NOTE 2 The flanking transmission may be measured directly using the intensity measuring method if the different special conditions required to obtain reliable results with this method are fulfilled. This should be shown in the test report unless reference can be given to a standard on this method.

Annex D
(informative)

Guidance on measurements in the low frequency bands

D.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 frequency bands are the cause of standing wave structures that are found in the whole room space.

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 not bad at low frequencies, the reproducibility may be very poor.

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.

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 the space to position the source and the microphones according to the requirements.

D.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 6.3.2) 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. This is also valid for the distances between microphone positions and the surface of the separating element.

D.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.

D.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 averaging the results. Therefore, the number of loudspeaker positions has to be increased; the minimum number should be three.

D.5 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.

D.6 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 E
(informative)

Forms for the expression of results

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

The curves of reference values shown in the forms are taken from ISO 717-1. 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 717-1.

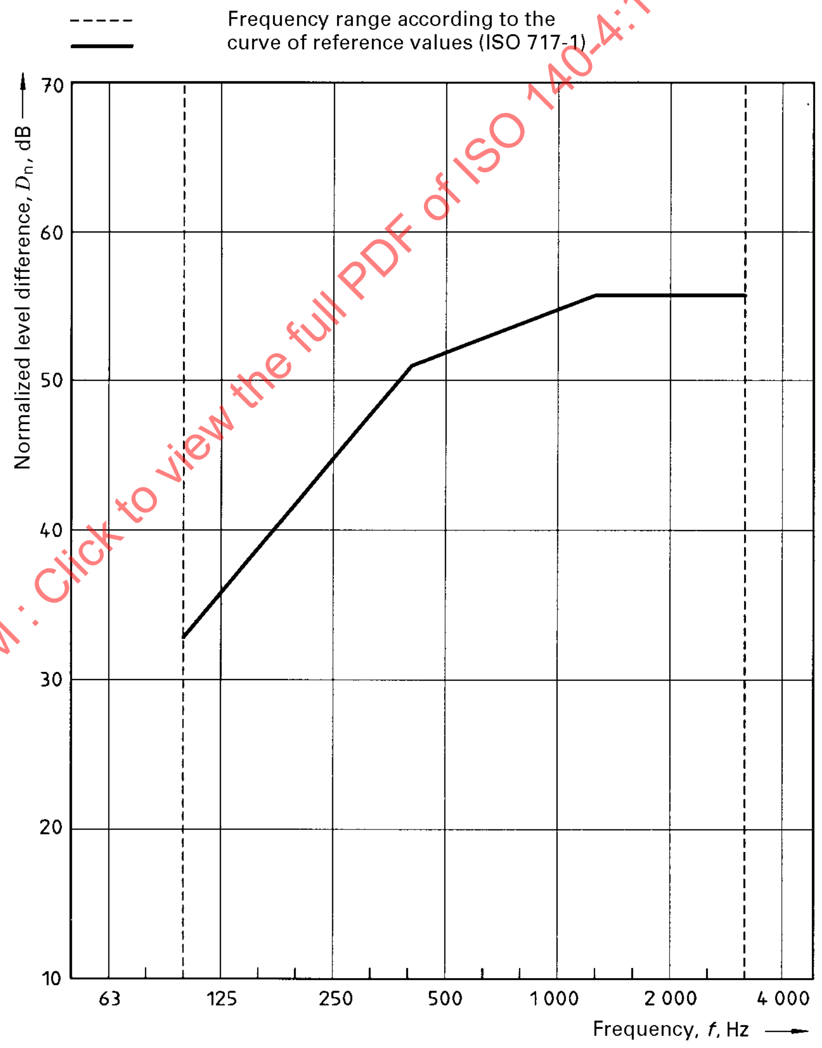
Normalized level difference according to ISO 140-4
Field measurements of airborne sound insulation between rooms

Client : Date of test :

Description and identification of the building construction and test arrangement, direction of measurement :

Source room volume : m³
Receiving room volume : m³

Frequency f Hz	D_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 717-1

$D_{n,w}$ $(C;C_{tr})$ = (;) dB; $C_{50\text{-}3150}$ = dB; $C_{50\text{-}5000}$ = dB; $C_{100\text{-}5000}$ = dB

Evaluation based on field measurement results obtained by an engineering method $C_{tr,50\text{-}3150}$ = dB; $C_{tr,50\text{-}5000}$ = dB; $C_{tr,100\text{-}5000}$ = dB

No. of test report : Name of test institute :

Date : Signature :

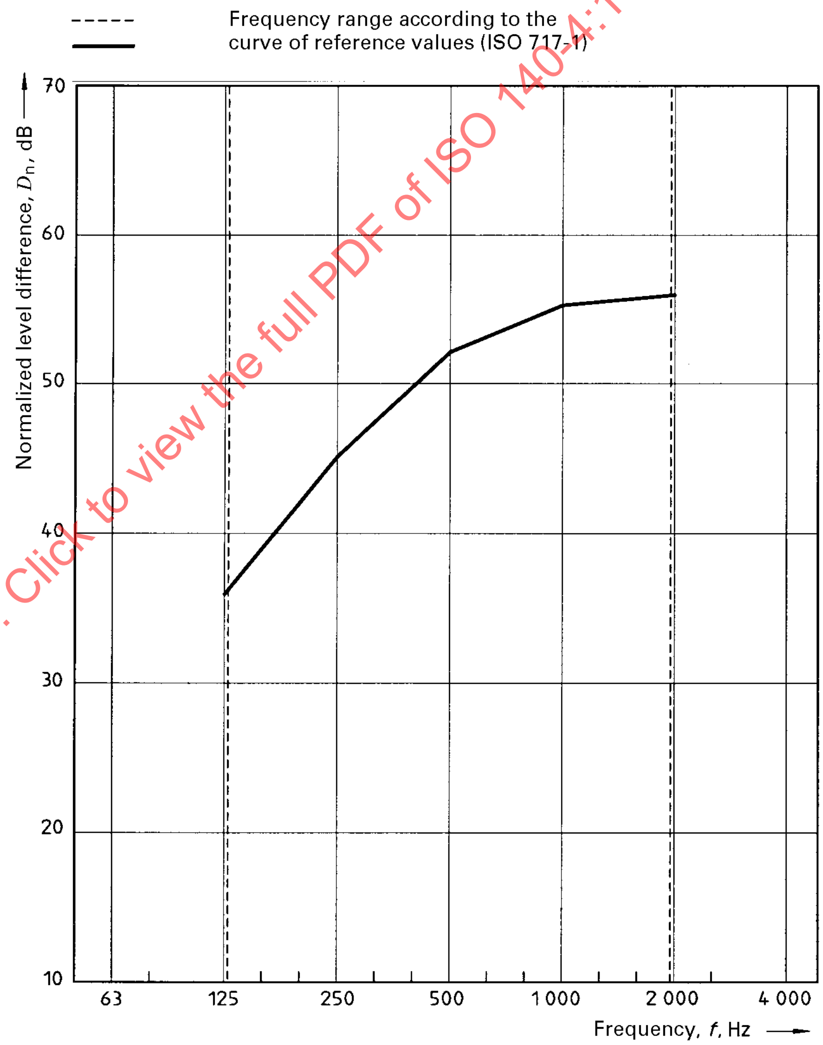
Normalized level difference according to ISO 140-4
Field measurements of airborne sound insulation between rooms

Client : Date of test :

Description and identification of the building construction and test arrangement, direction of measurement :

Source room volume : m³
Receiving room volume : m³

Frequency f Hz	D_n (octave) dB
63	
125	
250	
500	
1 000	
2 000	
4 000	



Rating according to ISO 717-1

$D_{n,w}$ $(C;C_{tr})$ = (;) dB; $C_{63\text{-}2000}$ = dB; $C_{63\text{-}4000}$ = dB; $C_{125\text{-}4000}$ = dB

Evaluation based on field measurement results obtained by an engineering method

$C_{tr,63\text{-}2000}$ = dB; $C_{tr,63\text{-}4000}$ = dB; $C_{tr,125\text{-}4000}$ = dB

No. of test report : Name of test institute :

Date : Signature :

Standardized level difference according to ISO 140-4
Field measurements of airborne sound insulation between rooms

Client :

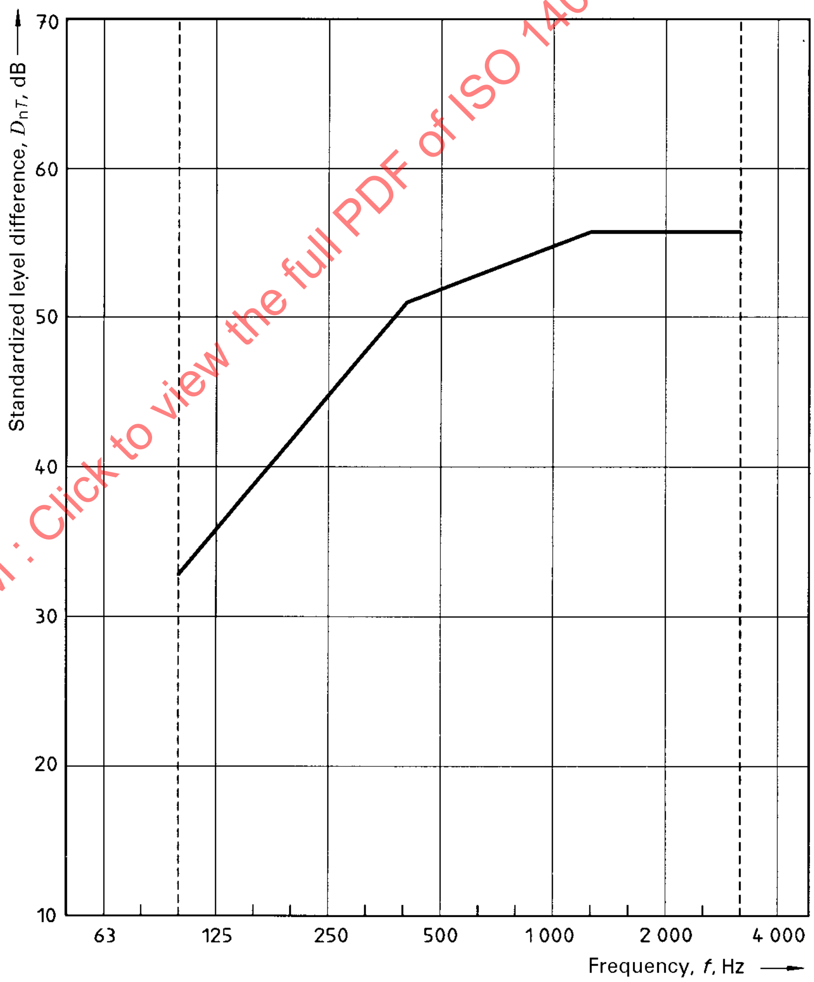
Date of test :

Description and identification of the building construction and test arrangement, direction of measurement :

Source room volume : m³
Receiving room volume : m³

- - - - - / ——— Frequency range according to the curve of reference values (ISO 717-1)

Frequency f Hz	D_{nT} (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 717-1

$D_{nT,w}$ $(C;C_{tr})$ = (;) dB; $C_{50-3150}$ = dB; $C_{50-5000}$ = dB; $C_{100-5000}$ = dB

Evaluation based on field measurement results obtained by an engineering method

$C_{tr,50-3150}$ = dB; $C_{tr,50-5000}$ = dB; $C_{tr,100-5000}$ = dB

No. of test report :

Name of test institute :

Date :

Signature :