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

Part 2: Field measurements

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

Partie 2: Mesurages in situ

Reference number
ISO 15186-2:2003(E)

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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.

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

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

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

ISO 15186-2 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*.

ISO 15186 consists of the following parts, under the general title *Acoustics — Measurement of sound insulation in buildings and of building elements using sound intensity*:

— *Part 1: Laboratory measurements*

— *Part 2: Field measurements*

— *Part 3: Laboratory measurements at low frequencies*

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

Part 2:
Field measurements

1 Scope

1.1 General

This part of ISO 15186 specifies a sound intensity method to determine the *in-situ* sound insulation of walls, floors, doors, windows and small building elements. It is intended for measurements that have to be made in the presence of flanking transmission. It can be used to provide sound power data for diagnostic analysis of flanking transmission or to measure flanking sound insulation parameters.

This part of ISO 15186 can be used by laboratories that could not satisfy the requirements of ISO 15186-1, which deals with laboratory measurements with no or little flanking transmission. ISO 15186-3 deals with measurements under laboratory conditions, at low frequencies.

This part of ISO 15186 also describes the effect of flanking transmission on measurements made using the specified method, and how intensity measurements can be used

— to compare the *in-situ* sound insulation of a building element with laboratory measurements where flanking has been suppressed (i.e. ISO 140-3),

— to rank the partial contributions for building elements, and

— to measure the flanking sound reduction index for one or more transmission paths (for validation of prediction models such as those given in EN 12354-1).

This method gives 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.

1.2 Precision

The reproducibility of this intensity method is estimated to be equal to or better than that of the methods of ISO 140-10 and ISO 140-4, when measuring a single small and large building element, respectively.

NOTE 1 If sound reduction measures made using this method are to be compared with those made using the conventional reverberation room method in various parts of ISO 140, then it will be necessary to introduce an adaptation term that reflects the bias between the test methods. This term is given in Annex A.

NOTE 2 Some information about the accuracy for this part of ISO 15186 and its relationship to the sound reduction index measured according to ISO 140-3 and ISO 140-4 is given in Annex B.

NOTE 3 Flanking transmission is discussed in Annex C.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 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 140-4:1995, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 4: Field measurements of airborne sound insulation between rooms*

ISO 140-10:1991, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 10: Laboratory measurement of airborne sound insulation of small building elements*

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

IEC 60942:1991, *Sound calibrators*

IEC 61043:1993, *Instruments for the measurement of sound intensity*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply. The subscripts are defined in Table 1.

NOTE In this part of ISO 15186, quantities that represent the average over the measurement surface are explicitly identified using a bar over the measured quantity. For example, $\overline{I}_{\mathrm{n}}$ is the average normal intensity over the measurement surface, whereas the quantity, I_{n}, without the bar, is the normal intensity obtained at a single point on the measurement surface. This explicit identification of surface average quantities is intended to help the user quickly identify surface average quantities and to make the nomenclature consistent with the ISO 9614 series. This may make some definitions appear different from those in ISO 15186-1 and ISO 15186-3 although they are functionally identical.

3.1
average sound pressure level in a source room

L_{p1}

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 (20 µPa), 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, window, etc.) is of significant influence

NOTE 1 This quantity is given in decibels.

NOTE 2 Adapted from the complete definition given in ISO 140-4.

3.2
apparent sound reduction index

R'

ten times the logarithm to the base 10 of the ratio of the sound power incident on the building element under test to the total sound power radiated into the receiving room by direct transmission and all flanking paths

NOTE 1 Unless special efforts have been made to suppress flanking transmission (i.e. those defined in ISO 140-1), the measured sound power will contain a flanking component. Annex C provides more details.

NOTE 2 The expression sound transmission loss, which is equivalent to sound reduction index is also in use.

NOTE 3 Adapted from the complete definition given in ISO 140-4.

3.3
sound intensity
$\vec{I}$
time-averaged rate of flow of sound energy per unit area in the direction of the local particle velocity, in watts per square metre, which is a vector quantity and is equal to

$$\vec{I} = \frac{1}{T} \int_0^T p(t) \cdot \vec{u}(t) \, \mathrm{d}t \qquad (1)$$

where

$p(t)$ is the instantaneous sound pressure at a point, in pascals;

$\vec{u}(t)$ is the instantaneous particle velocity at the same point, in metres per second;

T is the averaging time, in seconds.

NOTE This quantity is measured in watts per square metre.

3.4
normal sound intensity
I_n
component of the sound intensity, in watts per square metre, in the direction normal to a measurement surface defined by the unit normal vector $\vec{n}$

$$I_\mathrm{n} = \vec{I} \cdot \vec{n} \qquad (2)$$

where $\vec{n}$ is the unit normal vector directed out of the volume enclosed by the measurement surface

3.5
normal sound intensity level
L_{I_n}
ten times the logarithm to the base 10 of the ratio of the unsigned value of the normal sound intensity to the reference intensity I_0 as given by

$$L_{I_\mathrm{n}} = 10 \lg \frac{|I_\mathrm{n}|}{I_0} \qquad (3)$$

where

$I_0 = 10^{-12}$ W/m²

3.6
surface pressure-intensity indicator
F_{pI_n}
difference, in decibels, between the sound pressure level, $\overline{L}_p$, and the normal sound intensity level, $\overline{L}_{I_\mathrm{n}}$, on the measurement surface, both being time- and surface-averaged, given by

$$F_{pI_\mathrm{n}} = \overline{L}_p - \overline{L}_{I_\mathrm{n}} \qquad (4)$$

where

$$\overline{L}_p = 10 \lg\left(\frac{1}{S_\mathrm{M}}\sum_{i=1}^{N} S_{\mathrm{M}_i} 10^{0,1\overline{L}_{pi}}\right) \text{ dB} \qquad (5)$$

and

$$\overline{L}_{I_\mathrm{n}} = 10 \lg\left|\frac{1}{S_\mathrm{M}}\sum_{i=1}^{N} \frac{S_{\mathrm{M}_i}\overline{I}_{\mathrm{n}_i}}{I_0}\right| \text{ dB} \qquad (6)$$

where

$\overline{L}_{p_i}$ is the time- and surface-averaged sound pressure level measured on the ith sub-area;

$\overline{I}_{n_i}$ is the time- and surface-averaged signed normal intensity measured on the ith sub-area, and there are N sub-areas having a total area of S_M

$$S_\mathrm{M} = \sum_{i=1}^{N} S_{\mathrm{M}_i} \qquad (7)$$

NOTE In the limit of equal sub-areas, this indicator corresponds to the negative partial power indicator F_3 defined in ISO 9614-1 and signed pressure-intensity indicator, F_{pI_n}, defined in ISO 9614-3.

3.7
pressure-residual intensity index
δ_{pI0}
difference, in decibels, between the indicated sound pressure level, L_p, and the indicated sound intensity level, L_I, when the intensity probe is placed and oriented in a sound field such that the sound intensity is zero

$$\delta_{pI0} = \left(L_p - L_{I\delta}\right) \qquad (8)$$

where $L_{I\delta}$ is the level of the residual intensity and is given by

$$L_{I\delta} = 10 \lg\frac{|I_\delta|}{I_0} \text{ dB} \qquad (9)$$

NOTE This definition is consistent with that given in the ISO 9614 series. Details for determining δ_{pI0} are given in IEC 61043.

3.8
apparent intensity sound reduction index
R'_I
index, in decibels, for a building element that separates one source room and one receiving room, which also may be the outside, defined as

$$R'_I = \left[L_{p1} - 6 + 10 \lg\left(\frac{S}{S_0}\right)\right] - \left[\overline{L}_{I_\mathrm{n}} + 10 \lg\left(\frac{S_\mathrm{M}}{S_0}\right)\right] \qquad (10)$$

where the first term relates to the incident sound power in the source room and the second term relates to the sound power radiated from the building element(s) contained within the measurement volume in the receiving room, and

L_{p1} is the average sound pressure level in the source room;

S is the area of the separating building element under test or, in the case of staggered or stepped rooms, that part of the area common to both the source and receiving rooms;

$\bar{L}_{In}$ is the average normal sound intensity level over the measurement surface(s) in the receiving room;

S_M is the total area of the measurement surface(s);

S_0 = 1 m^2

NOTE 1 Where the intent is to assess the apparent sound reduction index due to all elements radiating sound into the receiving room, the contribution from this index R'_I may be combined with the intensity sound reduction index for each flanking element $R_{I\,Fj}$ (see 3.9), as described in Annex C.

NOTE 2 The weighted apparent intensity sound reduction index, R'_{Iw}, is calculated according to ISO 717-1 by replacing R' with R'_I.

NOTE 3 This index R'_I differs fundamentally from the apparent sound reduction index R' of ISO 140-4 where total sound power from all receiving sources is measured. The definition of apparent intensity sound reduction index allows directionality of the intensity probe to be used, to selectively measure the sound power from each receiving room surface as desired. In principle, by combining the sound power from all surfaces in the receiving room, an estimate of R' can be obtained; Annex C discusses this in more detail.

3.9
intensity sound reduction index for flanking element *j*

$\boldsymbol{R}_{I\,\mathrm{F}\,j}$

when a building element separates the source room from the receiving room, this index is defined for a flanking surface j in the receiving room as

$$R_{I\,\mathrm{F}\,j} = \left[L_{p1} - 6 + 10\ \lg\left(\frac{S}{S_0}\right)\right] - \left[\bar{L}_{In\,j} + 10\ \lg\left(\frac{S_{\mathrm{M}\,j}}{S_0}\right)\right] \qquad (11)$$

where the first term relates to the sound power incident on the separating element under test from the source room and the second term relates to the sound power radiated from the flanking surface j into the receiving room, and

L_{p1} is the average sound pressure level in the source room;

S is the area of the separating building element under test or, in the case of staggered or stepped rooms, that part of the area common to both the source and receiving rooms;

$\bar{L}_{In\,j}$ is the average normal sound intensity level over the measurement surface for the flanking element j in the receiving room;

$S_{\mathrm{M}\,j}$ is the total area of the measurement surface for the flanking element j in the receiving room;

S_0 = 1 m^2

NOTE Where the intent is to combine the effect of multiple elements radiating sound into the receiving room, the contribution from this index can be combined with the apparent intensity sound reduction index, R'_I for the separating element (see 3.8), as described in Annex C.

3.10
intensity element normalized level difference

$\boldsymbol{D}_{I\,\mathrm{ne}}$

difference given by

$$D_{I\,\mathrm{ne}} = \left[L_{p1} - 6\right] - \left[\bar{L}_{In} + 10\ \lg\left(\frac{S_{\mathrm{M}}}{A_0}\right)\right] \qquad (12)$$

where

L_{p1} is the average sound pressure level in the source room;

$\overline{L}_{I_n}$ is the average normal sound intensity level over the measurement surface in the receiving room;

S_M is the total area of the measurement surface(s);

$A_0 = 10\ m^2$

NOTE 1 The intensity element normalized level difference is used for small building elements.

NOTE 2 The weighted intensity element normalized level difference, $D_{I\,new}$, is calculated according to ISO 717-1 by replacing D_{ne} with $D_{I\,ne}$.

3.11
intensity normalized level difference
$\boldsymbol{D_{I\,n}}$

difference given by

$$D_{In} = \left[L_{p1} - 6\right] - \left[\overline{L}_{I_n} + 10\ \lg\left(\frac{S_M}{A_0}\right)\right] \quad (13)$$

where

L_{p1} is the average sound pressure level in the source room;

$\overline{L}_{I_n}$ is the average normal sound intensity level over the measurement surface in the receiving room;

S_M is the total area of the measurement surface(s);

$A_0 = 10\ m^2$

NOTE 1 This index is used when there is not a common building element separating the source room from the receiving room. Such a situation can occur when the rooms are diagonally separated.

NOTE 2 The weighted intensity normalized level difference, $D_{I\,nw}$, is calculated according to ISO 717-1 by replacing D_n with $D_{I\,n}$.

3.12
modified apparent intensity sound reduction index
$R'_{I\,m}$

index given by

$$R'_{I\,m} = R'_I + K_c \quad (14)$$

where the values of K_c are given in Annex A

NOTE 1 It is generally recognized that there is a difference between the sound reduction index determined by the sound intensity method [ISO 15186 (all parts)] and that measured by traditional methods (ISO 140-3, ISO 140-4 and ISO 140-10) at low frequencies. If the intensity results are to be compared to results measured using the traditional method, then the intensity results should be adjusted, giving the modified apparent intensity sound reduction index.

NOTE 2 The adaptation values K_c for *in-situ* measurements are consistent with K_c for measurements made in laboratories (i.e. ISO 15186-1). It is recognized that receiving room conditions may introduce a further bias, as discussed in Annex B.

NOTE 3 The weighted modified apparent intensity sound reduction index, $R'_{I\,\mathrm{mw}}$, is calculated according to ISO 717-1 by replacing R' with $R'_{I\,\mathrm{m}}$. Correspondingly the notation for $D_{I\,\mathrm{nemw}}$ is obtained.

3.13
measurement surface
surface totally enclosing the building element under test on the receiving side, scanned or sampled by the probe during the measurements

3.14
measurement distance
d_M
distance between the measurement surface and the building element under test in a direction normal to the element

3.15
measurement sub-area
part of the measurement surface being measured with the intensity probe using one continuous scan or that of a discrete position

3.16
measurement volume
volume bounded by the measurement surface(s), the building element under test, and any adjacent surfaces that do not radiate significant sound relative to the building element under test

NOTE See 6.4.2.

Table 1 — Subscripts

Subscript	Meaning
e	element
F	flanking
I	intensity
i	sub-area
j	loudspeaker position
m	modified
M	measurement
p	pressure
w	weighted

4 Instrumentation

4.1 General

The intensity-measuring instrumentation shall be able to measure intensity levels in decibels (ref. 10^{-12} W/m^2) in one-third-octave bands. The intensity shall be measured in real time when the scanning procedure is used. The instrument, including the probe, shall comply with class 1 of IEC 61043:1993.

The pressure-residual intensity index, δ_{pI0}, of the microphone probe and analyser shall be adequate to satisfy the requirements relative to the surface pressure-intensity indicator F_{pI_n} (see 6.5.4) for each measurement sub-area and for the total measurement surface.

NOTE In order to cover the full frequency range different spacers can be required between the probe microphones. The optimum combination of spacer and frequency band will depend on δ_{pI0} and F_{pI_n}. As an example, the following rule could apply:

— between 50 Hz and 500 Hz, use a 50 mm spacer;

— above 500 Hz, use a 12 mm spacer. The frequency response will normally have to be corrected above 2 000 Hz. Refer to probe manual for the appropriate method.

Often it is possible to cover the whole frequency range 100 Hz to 5 000 Hz by using a 12 mm spacer and two 12,5 mm microphones.

The equipment for sound pressure level measurements shall meet the requirements of ISO 140-4. In addition the microphone in the source room shall give a flat frequency response in a diffuse sound field.

4.2 Calibration

Verify compliance of the sound intensity instrument with IEC 61043 either at least once a year in a laboratory making calibrations in accordance with appropriate standards, or at least every 2 years if an intensity calibrator is used before each measurement series.

The following procedure shall be followed before each use of a sound intensity instrument to verify that it is operating correctly.

a) The instrument shall be allowed to warm up according to the manufacturer's instructions.

b) Calibrate both microphones for absolute pressure using an IEC 60942:1991, class 1 or better, sound pressure calibrator.

c) Apply the residual intensity testing device to the two microphones and measure the pressure-residual intensity index, δ_{pI0}, and ensure that the instrument is within the requirements for its class in the range which the residual intensity testing device operates. Phase compensation and any other procedures recommended by the manufacturer for performance enhancement may be applied. Phase compensation and pressure-residual intensity testing should preferably be done at a level close to the level of use.

d) If a sound intensity calibrator is available, use this to verify the intensity calibration directly.

5 Test arrangement

5.1 Selecting source and receiving room

In general, the building element under test will be part of a series of building elements separating two rooms. When choosing which room will be the source room and which will be the receiving room, consideration should be given to the following facts that can affect the quality of the measurement.

a) *Room absorption*: a highly absorptive receiving room having a short reverberation time is very beneficial, while a highly absorptive source room is not.

b) *Room volume*: the volume of the receiving room is not overly important, while a large source room can improve the accuracy of the intensity sound reduction index in the low frequencies.

c) *Room diffusion*: irregular room geometry and randomly located reflecting objects are beneficial in achieving a uniform sound field in the source room. Such properties are not of significant benefit for the receiving room.

5.2 Mounting conditions

If the intent is to compare with results from other standards (ISO 140-3 for doors, walls and floors, or ISO 140-10 for small building elements), the building element under test should meet the requirements of those standards regarding mounting and boundary conditions.

If the intent is to characterize *in-situ* performance with the field installation of the actual building element under test, then no changes to the building element under test shall be made unless explicitly noted in the test report.

6 Test procedure

6.1 General

For each loudspeaker position, measure the average sound pressure level in the source room, L_{p1}, and the average sound intensity level on a measurement surface in the receiving room, $\bar{L}_{I_n}$. Provided that the measurement conditions are satisfactory [i.e. the criterion of Equation (15) is satisfied], calculate the apparent intensity sound reduction index R'_I and/or the intensity sound reduction index $R_{I\,\mathrm{F}j}$ for flanking surface(s) j or, alternatively, the intensity normalized level difference, $D_{I\,\mathrm{n}}$.

6.2 Generation of sound field

The sound source, signal and loudspeaker positions shall meet the requirements of ISO 140-4.

6.3 Measurement of average sound pressure level in the source room

Measure the average sound pressure level in the source room according to the procedures given in ISO 140-4.

6.4 Initial test for suitability of the receiving room

6.4.1 Measurement field check

To test the suitability of the receiving room for intensity measurements, switch on the sound source in the source room and scan with the intensity probe diagonally across the building element under test at a distance of 0,1 m to 0,3 m (see 6.5.5). The receiving room may be any space meeting the requirements of the field indicator, F_{pI_n}, (see 4.1 and 6.5.4) and the background noise (see 6.7).

6.4.2 Flanking transmission check

Acoustic radiation from building elements adjacent to the measurement surface can adversely affect the accuracy of the measurements. Building elements that bound the measurement surface should not radiate significant sound power relative to the building element(s) under test. Annex C provides a method to determine if these surfaces will have an effect.

6.5 Measurement of average sound intensity level on the receiving side

6.5.1 General

The average sound intensity radiated by the building element shall be estimated for each loudspeaker position using either the scanning or discrete point method.

6.5.2 Measurement surface

On the receiving side, define a measurement surface that totally encloses the building element under test. For practicality, the surface may be formed from a number of smaller sub-areas.

If the building element under test is mounted in a niche, the measurement surface is normally the flat surface of the niche opening. The sound field is usually more uniform in the niche opening than inside the niche. If the building element under test is not mounted in a niche, or if the depth of the niche is less than 0,1 m, use a box-shaped measurement surface as shown in Figure 1. This will be the most common condition for small building elements. If the building element is a complete surface of the room, such as a partition wall, the measurement surface is a plane parallel to the wall, as shown in Figure 2.

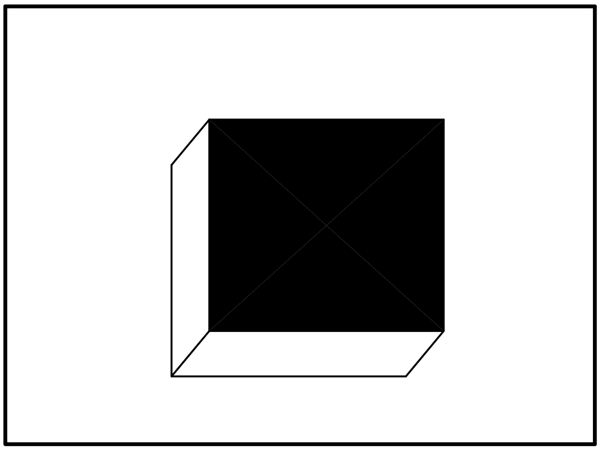
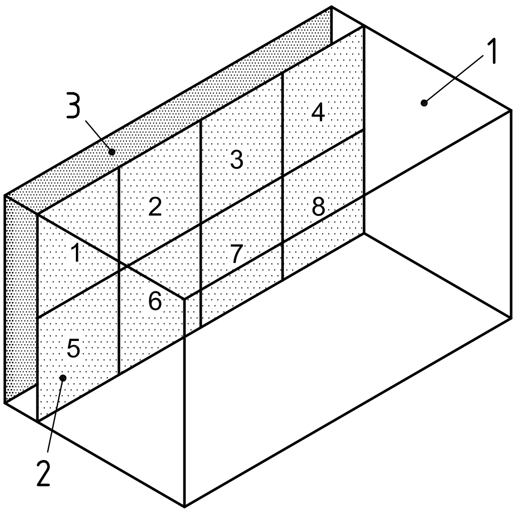


Figure 1 — Box-shaped measurement surface enclosing the building element under test (dark area)



Key

1 receiving room

2 measurement surface divided into eight sub-areas

3 building element under test (dark-shaded area)

NOTE In this figure eight sub-areas are identified. The actual number used is at the discretion of the operator.

Figure 2 — Planar measurement surface constructed from a series of sub-areas all of which are parallel to the large building element under test

For small building elements, hemispherical, cylindrical or partially box-shaped measurement surfaces may also be applicable.

Initially select a measurement distance between 0,1 m and 0,3 m. Avoid measurement distances shorter than 0,1 m because of the near field of the vibrating element. In the near field the intensity tends to change sign rapidly with position. When using box-shaped measurement surfaces, avoid measurement distances longer than 0,3 m.

As shown in Figure 1, four of the five faces of the box-shaped measurement surface intersect the perimeter of the element under test. These side surfaces will have a depth equal 0,1 m to 0,3 m, i.e. the distance between the frontal face and the specimen. Thus, complete sampling the side surfaces can include the effect of near-field radiation. This situation may be avoided by providing an offset of 0,1 m for the four sides of the box-shaped measurement surface when the sound power radiated by the building element under test is considerably greater than that radiated by non-specimen surfaces contained in the measurement volume. Radiation from the non-specimen surfaces may be viewed as being unwanted flanking and the criterion of Annex C.2 may be used to determine the suitability of this alternative measurement surface configuration.

The measurement surface should be chosen so that the measurement volume does not contain sound-absorbing surfaces that are not part of the specimen under test (e.g. thick pile carpet). If this is not possible, then absorbing surfaces that are not part of the specimen under test shall be shielded with a material having an absorption coefficient of less than 0,1 in each of the one-third-octave bands for which the test will be conducted. Failure to shield these surfaces can result in an underestimation of the radiated intensity and an overestimation of the apparent intensity sound reduction index.

6.5.3 Probe orientation

The orientation of the probe shall be normal to the measurement surface. The reported normal sound intensity, $\overline{I}_{\mathrm{n}}$, shall be positive for energy flowing from the building element under test.

6.5.4 Qualification of the measurement surface

Measure the time- and space-integrated normal sound intensity level, $\overline{L}_{I_{\mathrm{n}}}$ for the complete measurement surface either by the scanning or discrete point procedure. If possible, measure the time- and space-integrated sound pressure level, $\overline{L}_p$, simultaneously. The surface pressure-intensity indicator, $F_{pI_{\mathrm{n}}}$, provides an estimate of the quality of the measurement environment. A satisfactory environment is defined as being one that satisfies the criterion

$$F_{pI\mathrm{n}} < \delta_{pI0} - 7 \text{ dB for reflective test specimen, or } F_{pI\mathrm{n}} < 6 \text{ dB for absorptive test specimen} \qquad (15)$$

for each one-third-octave frequency band for which the intensity sound reduction index will be reported. A test specimen shall be considered absorptive for any one-third-octave band if the absorption coefficient exceeds 0,5.

NOTE A typical absorptive test specimen is a perforated panel in front of an absorber. Most other test specimens can be considered to be reflective.

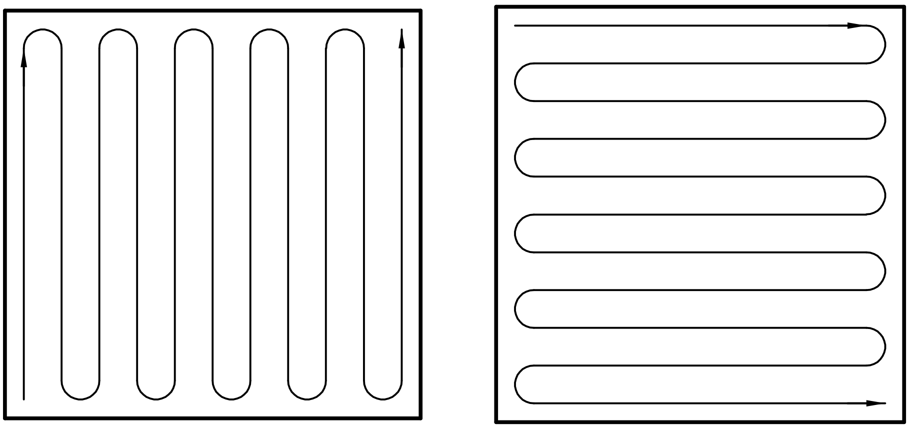
If the measured normal sound intensity, $\overline{I}_{\mathrm{n}}$, is negative, or if the surface pressure-intensity indicator, $F_{pI_{\mathrm{n}}}$ does not satisfy Equation (15), then improve the measurement environment. First, increase the measurement distance by 5 cm to 10 cm. If this fails, add sound-absorbing material to the receiving room.

Extraneous noise sources that are present when making *in-situ* measurements can create unacceptable measurement conditions. Such sources include flanking surfaces radiating into the receiving room. Such sources may have to be removed or shielded if an adequate measurement environment is to be achieved, as discussed in Annex C.

6.5.5 Scanning procedure

6.5.5.1 General

The measurement surface shall consist of one area or several sub-areas. The scanning time of each sub-area shall be proportional to the size of the area. Keep the scan speed constant. Select a speed between 0,1 m/s and 0,3 m/s. Interrupt the measurements when going from one sub-area to another. Avoid other stops.



NOTE The measured intensities are $\overline{L}_{I_{\mathrm{n}}1}$ and $\overline{L}_{I_{\mathrm{n}}2}$, respectively.

Figure 3 — Scan patterns for the first and second scans, differing in orientation by 90°

Scan each area or sub-area using parallel lines turning at each edge as shown in Figure 3. The required scanning line density depends on the uniformity of the sound radiation. Non-uniform radiation, which can be caused by leakages, requires a higher line density. Normally, select the distance between adjacent scan lines to be equal to the measurement distance, d_{M}.

If the measurement surface is box shaped as shown in Figure 1, or partially box-shaped, which may be the case for small building elements mounted at an edge or in a corner, give particular care to the areas close to the intersection between the box surface and the partition in which the building element under test is mounted. Each side of the box will be considered to be a subarea in the calculation procedure.

6.5.5.2 Repeatability check for scanning

The repeatability of the scanned intensity of each sub-area shall be checked before the data may be used in computing the average intensity of the measurement surface.

Once the initial test for the suitability of the receiving room has been passed (6.4), make the two scans as indicated in Figure 3. Record the measurements $\overline{L}_{I_{\mathrm{n}}1}$ and $\overline{L}_{I_{\mathrm{n}}2}$. Determine if the criterion of Equation (15) is satisfied for all one-third-octave bands measured:

$$\left|\overline{L}_{I_{\mathrm{n}}1} - \overline{L}_{I_{\mathrm{n}}2}\right| \leqslant 1{,}0 \text{ dB} \tag{16}$$

If the criterion of Equation (15) is satisfied, then the sub-area intensity is given by the arithmetic average of the two scan measurements:

$$\overline{L}_{I_{\mathrm{n}}ij} = \frac{1}{2}\left(\overline{L}_{I_{\mathrm{n}}1} + \overline{L}_{I_{\mathrm{n}}2}\right) \tag{17}$$

where the subscript i indicates the sub-area and j indicates the position of the loudspeaker when the measurement was made.

If the criterion of Equation (15) is not satisfied, repeat the two scans again and check if the repeat measurements satisfy the criterion of Equation (15). If the requirement is not fulfilled, change the scanning line density, measurement surface or measurement environment and repeat the procedure until the requirement is fulfilled. If, despite these efforts, it is impossible to comply with these requirements, the results may still be given in the test report providing that all deviations from the requirements of this method are clearly stated.

6.5.6 Procedure for discrete positions

As an alternative to scanning, fixed positions may be used on the measurement surface described in 6.5.2. Initially select the distance between the probe positions to be approximately d_M, where d_M is the measurement distance from the building element under test. If a building element under test has strong sound leaks or inhomogeneous sound flow, use a denser measurement grid but keep the measurement distance constant. For the measurements, follow the procedures of a grade 2 method as specified in ISO 9614-1:1993. Check the adequacy of the chosen array of measurement positions using Annex B of ISO 9614-1:1993. Measure for at least 10 s in each probe position.

6.6 Combining results of multiple sub-areas and loudspeaker positions

For each sub-area, apply the procedures of 6.5.5 or 6.5.6. This shall be repeated for each loudspeaker position.

If the measurement surface is divided into M sub-areas, each with the area, S_{Mi}, and there are N source loudspeaker positions, evaluate the average sound intensity, $\overline{I}_n$, for the measurement surface from

$$\overline{I}_n = \frac{I_0}{N} \sum_{j=1}^{N} \frac{1}{S_M} \sum_{i=1}^{M} \left[S_{M_i} \left(10^{0,1 \overline{L}_{I_{n ij}}} \right) \mathrm{sgn}\left(\overline{I}_{n\, ij} \right) \right] \ \frac{\mathrm{W}}{\mathrm{m}^2} \tag{18}$$

where

j indicates the loudspeaker position;

i indicates the sub-area;

sgn ($\overline{I}_{n\, ij}$) takes the value of negative unity if the sound intensity for a measurement sub-area is directed into the measurement volume, otherwise it is unity;

S_M is the total area of the measurement surface and is given by

$$S_M = \sum_{i}^{M} S_{M_i} \quad \mathrm{m}^2 \tag{19}$$

It is possible for $\overline{I}_n$, evaluated using Equation (18), to take a negative value, indicating that the average intensity flow through the measurement surface is toward the specimen under test. In this case, the sound insulation measures are not defined and shall not be reported.

NOTE A negative intensity can occur when the receiving room is excessively reverberant or when there are extraneous noise sources (such as flanking surfaces) exterior to the measurement volume. Procedures to correct this are given in 6.5.4 and Annex C.

The surface average estimate of the normal sound intensity level, $\overline{L}_{I_n}$, is obtained using

$$\overline{L}_{I_n} = 10 \lg \frac{\left| \overline{I}_n \right|}{I_0} \mathrm{dB} \tag{20}$$

where the normal sound intensity, $\overline{I}_n$, takes the surface-averaged value obtained using Equation (18).

Similarly, calculate the surface pressure-intensity indicator using

$$F_{pI_n} = 10 \lg \left[\frac{1}{N} \sum_{j=1}^{N} \frac{1}{S_M} \sum_{i=1}^{M} S_{M_i} \times 10^{0,1 \overline{L}_{p ij}} \right] - \overline{L}_{I_n} \ \ \mathrm{dB} \tag{21}$$

where $\overline{L}_{p_{ij}}$ is the surface-averaged sound pressure level over sub-area i for the j^{th} loudspeaker position.

For building elements separating the source and receiving rooms, the apparent intensity sound reduction index, R'_I, is given by Equation (10), where the surface intensity computed using Equation (18) is positive and the criterion of 6.5.4 is satisfied.

6.7 Background noise

Both the sound pressure level and the sound intensity level shall be at least 10 dB higher than the background sound pressure level. These requirements may be tested by applying the following procedure. If the criterion for the field indicator F_{pI_n} is satisfied (see 6.5.4), then lower the source level by 10 dB. If F_{pI_n} is changed by less than 1 dB, then the requirements are fulfilled.

NOTE The criterion for background sound level is more stringent than the corresponding criterion in ISO 140-4, because the intensity measurement cannot be corrected for background sound pressure level.

6.8 Frequency range of measurements

Measure the sound pressure level and the sound intensity level using one-third-octave band filters having at least the following centre frequencies, in hertz:

100 125 160 200 250 315 400 500 630 800 1 000 1 250 1 600 2 000 2 500 3 150

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

50 63 80

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

4 000 5 000

Octave band values, if needed, shall be calculated from one-third-octave levels using the procedure defined in ISO 140-4.

6.9 Quantities to be determined

Determine relevant quantities from R'_I, $R'_{I\,\mathrm{M}}$, $R_{I\mathrm{F}j}$, $D_{I\mathrm{n}}$, $D_{I\,\mathrm{ne}}$ and F_{pI_n}. In the special case that no common areas exist, R'_I and $R_{I\,\mathrm{F}j}$ are undefined and shall be replaced by $D_{I\,\mathrm{ne}}$ and $D_{I\,\mathrm{n}}$ respectively.

7 Expression of results

Data assessing the sound insulation (e.g. R'_I, $R_{I\,\mathrm{F}j}$, $D_{I\,\mathrm{n}}$, $D_{I\,\mathrm{ne}}$) and the surface pressure-intensity indicator, F_{pI_n}, shall be given in tabular form to an accuracy of one decimal place for all measurement frequencies. These data may also be given in graphical form with the level in decibels plotted against frequency on a logarithmic scale, and the following dimensions shall be used:

— 5 mm for a one-third octave;

— 20 mm for 10 dB.

8 Test report

The test report shall state the following:

a) name of organization that has performed the measurements;

b) identification of test site;

c) name of client;

d) date of test;

e) the reference number of this part of ISO 15186 and any requirements that were not satisfied;

f) description of the building element under test, including mounting, sealing and mass per unit area;

g) volume and description of measurement rooms; major flanking paths should be clearly indicated, if identified;

h) the common area of the building element under test, s, with a special indication ($<$ 10 m^2) if it is less than 10 m^2, and the area of the measurement surface s_M;

i) for all one-third-octave bands where the surface average normal sound intensity [as defined by Equation (18)] is positive, report the relevant sound insulation data (e.g., R'_I, $R'_{I\,\mathrm{F}j}$, $D_{I\,\mathrm{ne}}$); if modified values are reported as well, then the value of K_c shall also be given;

j) weighted sound reduction indexes shall only be reported when the surface average normal sound intensity [as defined by Equation (18)] is positive for all one-third-octave bands used in determining the weighted index.

k) surface pressure-intensity indicator, F_{pI_n}, and pressure-residual intensity index, δ_{pI0} as a function of frequency;

l) measurement distance and shape and area of the measurement surface; description of measurement segment(s); spacing between scan lines or measurement grid for discrete points, depending on the test method used;

m) information regarding the measurement equipment, including the probe (microphone diameter and spacing).

NOTE For evaluation of the weighted sound reduction indexes, see ISO 717-1.

Annex A
(normative)

Adaptation term K_c

It is generally recognized that if sound reduction measures made using the method of this part of ISO 15186 are to be compared with those made using the conventional reverberation room method specified in ISO 140-3, ISO 140-4 or ISO 140-10, then it will be necessary to introduce an adaptation term that reflects the bias between the test methods.

For the purposes of this part of ISO 15186, the following values of K_c shall be used.

Provided that the traditional measurements according to ISO 140 have been taken in a well-defined receiving room

$$K_c = 10 \lg \left(1 + \frac{S_{b2}\lambda}{8V_2} \right) \text{ dB} \quad \text{(A.1)}$$

where

S_{b2} is the area of all the boundary surfaces in the receiving room;

V_2 is the volume of the receiving room;

λ is the wavelength of the mid-band frequency.

When the traditional measurements according to ISO 140-3 have been taken in a room that is not well defined, K_c has the values given in Table A.1.

NOTE The values in Table A.1 have been calculated based on the following values of the room parameters:

S_{b2} = 117 m^2;

V_2 = 81 m^3 (4,5 × 6,0 × 3,0).

These dimensions have been selected to be a compromise between two commonly used room sizes in acoustic laboratories: approximately 50 m^3 and 100 m^3 respectively. The preferred solution is to use the Equation whenever possible.

Table A.1

Frequency Hz	K_c	**Frequency** Hz	K_c	**Frequency** Hz	K_c
50	3,5	250	1,0	1 250	0,2
63	3,0	315	0,8	1 600	0,2
80	2,5	400	0,6	2 000	0,1
100	2,1	500	0,5	2 500	0,1
125	1,7	630	0,4	3 150	0,1
160	1,4	800	0,3	4 000	0,1
200	1,2	1 000	0,3	5 000	0,1

Additional bias and precision considerations related to the effects of flanking for the measurements of this part of ISO 15186 are presented in Annex B.

Annex B
(informative)

Estimated precision and bias of the method

B.1 General

This annex provides an estimate of the precision with which this part of ISO 15186 can reproduce the apparent sound reduction index, R', as defined by ISO 140-4 (large building elements) and ISO 140-10 (small building elements) when measuring the same building element with the same mounting and boundary conditions.

It should be noted that unless shielding is used, the apparent sound reduction index as measured by ISO 140-4 includes all flanking paths to the receiving room and the corresponding measures made using the intensity method require the summation of the intensity over all the receiving room surfaces. Failure to sample adequately all significant radiating surfaces will result in a large and negative bias term K_2. Thus, the bias term may be used to provide guidance when deciding if all significant sources have been sampled.

B.2 Estimated bias term, K_2

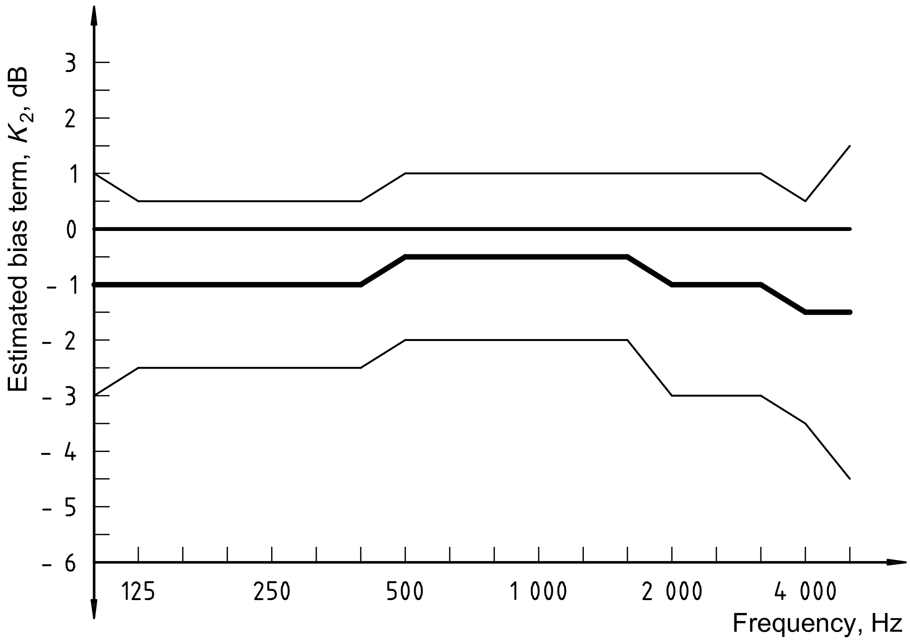
It is generally recognized that if sound reduction measures made using this part of ISO 15186 are to be compared with those made using ISO 140-4 (R'_{140}), then it will be necessary to introduce an adaptation term, K_2, that reflects the bias between the test methods

$$K_2 = R'_{140} - R'_{I\,\mathrm{M}} \quad \mathrm{dB} \tag{B.1}$$

The cause(s) of the bias will not always be known in each situation.

It is realistic to expect that the bias and precision for the method of this part of ISO 15186 will be a function of both the specimen under test and the receiving room environment. For this reason, it is not possible to provide a single bias estimate that is applicable to all situations that can be encountered when applying the method of this part of ISO 15186. However, it is possible to define a range for the values.

Figure B.1 shows the precision and bias for the method of ISO 15186-1 when applied to a series of doors, windows and walls. This can be viewed as defining a best case for the precision for the method of this part of ISO 15186, which might apply when the receiving room is large, well defined, and radiation from flanking surfaces is suppressed.



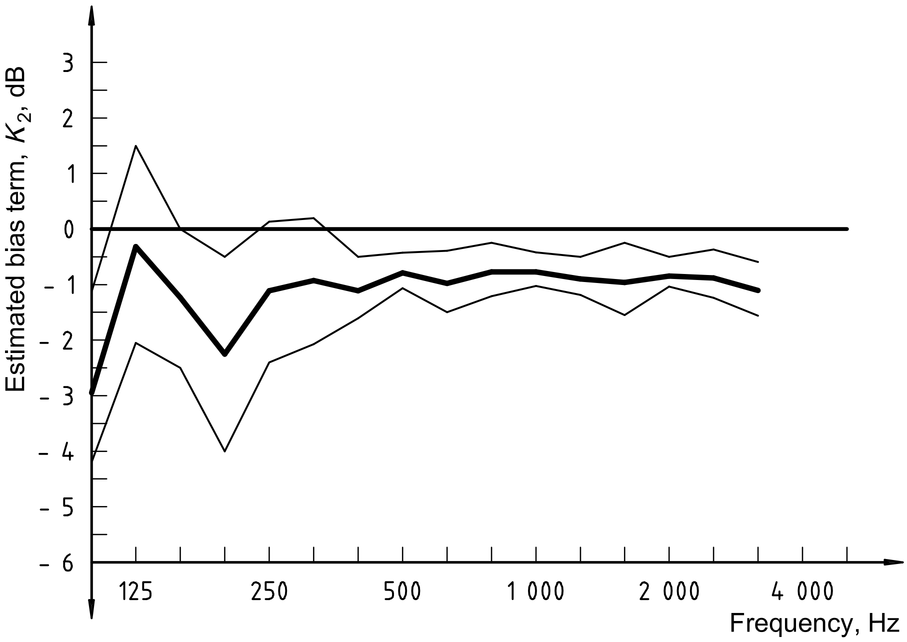
NOTE 1 The data (taken from reference [6]) are an average of the measured results made in three laboratories for a series of doors, windows and walls.

NOTE 2 The precision is expressed in terms of the mean bias term K_2 (bold line) and the standard deviation (normal line) of the sample.

Figure B.1 — Estimate of the precision with which the method of ISO 15186-1 can reproduce ISO 140-3 results

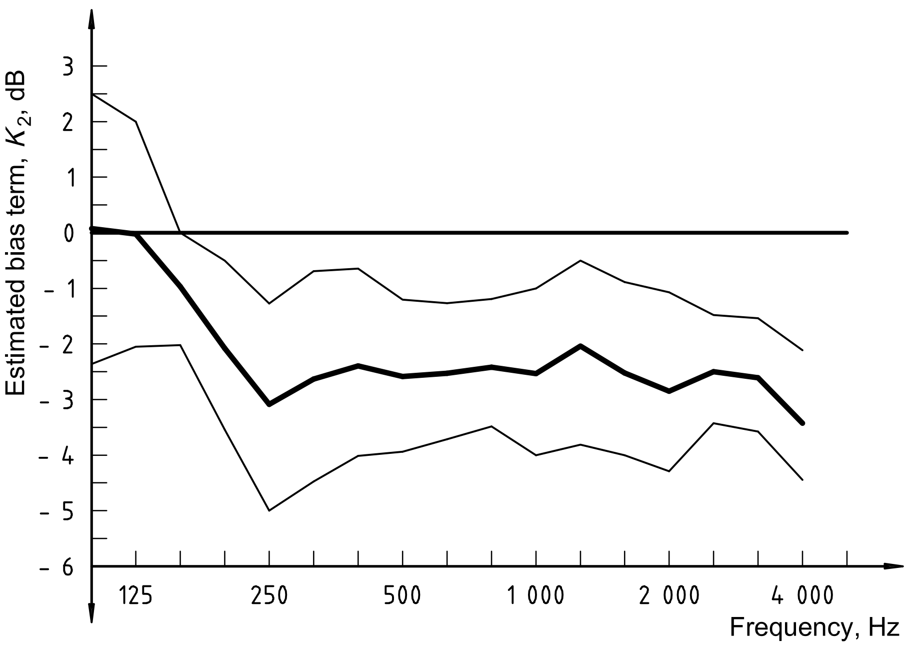
In-situ measurements made in the presence of strong flanking and in small receiving rooms should be the worst case for precision. Results from two flanking facilities are shown in Figures B.2 and B.3.

The data shown in Figure B.2 are the results of fourteen measurements of heavy monolithic constructions made in the same laboratory. They exhibit a similar, but increased, bias term K_2 relative to that for measurements in accordance with ISO 15186-1 shown in Figure B.1. Comparing the standard deviations shown in Figures B.1 and B.2, it is evident that the standard deviation is smaller for the set of measurements in the single laboratory (Figure B.2). This implies that there may be significant variation in K_2 between laboratories that are presumably due to differences in receiving room conditions and the type of specimens tested.



NOTE The data are for 14 cases measured in the same laboratory. The precision is expressed in terms of the mean bias term K_2 (bold line) and the standard deviation (normal line) of the sample.

Figure B.2 — Estimate of the precision with which the method of this part of ISO 15186 can reproduce ISO 140-4 results when measuring heavy monolithic constructions



NOTE 1 The data are from 34 measurements of lightweight double-leaf constructions, measured in the same laboratory. The precision is expressed in terms of the mean bias term K_2 (bold line) and the standard deviation (normal line) of the sample.

NOTE 2 For this situation, the bias term is larger than those shown in Figures B.1 and B.2.

Figure B.3 — Estimate of the precision with which the method of this part of ISO 15186 can reproduce ISO 140-4 results when measuring lightweight constructions

The data comprising Figure B.3 were analysed to determine if the bias term was a function of the surface being measured; partition or flanking element. The bias term proved to be nearly identical. However the uncertainty in the estimate for flanking surfaces is greater, especially for frequencies below 250 Hz. This might be due to the combination of several factors, including the following:

— high sound insulation shielding is necessary due to the fact that well below the critical frequency (approximately 2 500 Hz for these cases) the flanking surfaces radiate very little sound power;

— a reduced pressure-residual intensity index in the low frequencies will reduce the precision of intensity estimates;

— a low mode count in the receiving room will reduce the accuracy of the ISO 140 methods in the low frequencies;

— sampling errors might be introduced by the pronounced gradient in the radiated intensity of flanking surfaces as the measurement position is moved away from the excitation junction.

Comparison of Figures B.1 to B.3 indicates that the expected bias will be a function of the measurement situation (determined by the degree of flanking, room volumes, amongst others) and it is not feasible to specify a single bias and precision. However, it is expected that measurements will typically fall in the range defined by Figures B.1, B.2 and B.3.

B.3 Precision

The estimated standard deviation with which the modified intensity sound reduction will reproduce the ISO 140 result for large or small building elements is expected to fall in the range defined by Figures B.1, B.2 and B.3.

Annex C
(informative)

Measurement and the effect of flanking transmission

C.1 General

Since the requirement for suppressed flanking transmission, as defined in ISO 140-1, is not required in this part of ISO 15186, it is assumed that measurements conducted using the method of this part of ISO 15186 will have some flanking component associated with them. The magnitude of the flanking transmission and its effect on the apparent (intensity) sound reduction index is a complex function involving the building surfaces and the junctions connecting them.

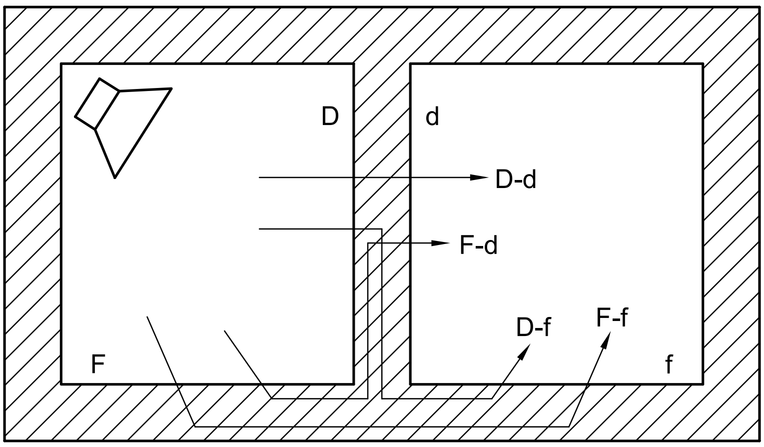
By selecting a measurement surface that totally encloses the surface of interest, it is possible to discriminate against power radiated from other receiving room surfaces and, in theory, the method measures only the sound power radiated by the surfaces contained in the measurement volume. Thus, the number of flanking paths in the estimate of the apparent intensity sound reduction index will depend on which receiving room surfaces are contained in the measurement volume.

With the appropriate selection of measurement surfaces, the intensity technique may be used to measure the sound power of the various elements, and this may be used to rank order the radiated sound power from different elements.

It should be noted that while the method allows for the effects of receiving room flanking to be largely removed, it cannot compensate for flanking that occurs in the source room. Figure C.1, which shows only the first-order flanking paths involving the wall/floor junction, illustrates that all receiving rooms surfaces, even the nominally separating building elements, will have a flanking component.

NOTE A first-order flanking path is one that involves a single source surface, a single junction and a single receiving room surface.

It is for this reason that *in-situ* measurements made in accordance with this part of ISO 15186 may not compare favourably with laboratory results for the nominally identical building element obtained with the method of ISO 15186-1 or ISO 140-3, where flanking in both the source and receiving rooms has been suppressed.



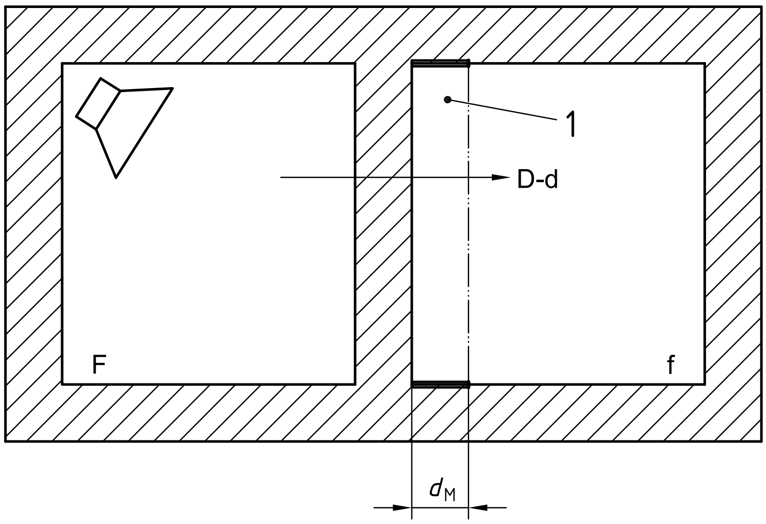
NOTE There will also be higher order flanking paths, which have been omitted for clarity.

Figure C.1 — Idealized sketch for monolithic constructions showing the direct transmission and the first-order flanking paths at the wall/floor junction between two rooms sharing a common partition

Flanking transmission will increase the amount of extraneous noise in the receiving room and it may be necessary to add significant absorption to the receiving room in order to obtain a satisfactory measurement environment [i.e. to satisfy Equation (15)]. In extreme cases, it may also be necessary to shield one or more receiving room flanking surfaces.

C.2 Check for flanking transmission

Before conducting measurements, it is very useful to identify the acoustic sources close to the measurement surface, particularly those that might be contained in the measurement volume. Figure C.2 shows how a portion of a flanking surface can be included in the measurement volume. For the portion of the flanking surface contained in the measurement volume to have a negligible effect on the estimate of the apparent sound reduction index of the partition, the sound power radiated by the partition has to be considerably greater than the sound power radiated by the extraneous noise source (i.e. portion of the flanking surfaces) contained in the measurement volume. Typically, an extraneous noise source contained in the measurement volume will cause an underestimation of the apparent intensity sound reduction index of the specimen under test.



NOTE The dark lines indicate the portion of flanking surfaces that are contained in the measurement volume.

Key

1 measurement surface

Figure C.2 — Sketch showing a measurement surface used to sample the partition wall

Using the indicated measurement surface, and without the shielding of any surfaces, the following paths will be measured D-d, F-d and a fraction of D-f and F-f. (These paths are shown in Figure C.1.)

The following procedure may be used to assess if an adjacent radiating surface is likely to affect the estimate of the apparent intensity sound reduction for the surface under test. Select the measurement surface and the measurement distance, d_M. Use the normal component of the intensity along a diagonal line across the surface (from 6.4.1) to obtain a crude estimate of the surface intensity, $\overline{L}_{I_n M_s} - L_{I_n F_s}$. Next, orient the probe toward the flanking surface and measure the intensity along a line in the plane of the measurement surface that is a distance, d_m, from the flanking surface. This intensity is defined as $\overline{L}_{I_n F_s}$.

If in measuring $\overline{L}_{I_n M_s}$ or $\overline{L}_{I_n F_s}$ the measurement field was unsatisfactory [i.e. Equation (15) was not satisfied], then try to improve the field by placing additional absorption in the measurement room. Sound-absorbing material shall not be placed within the measurement volume.

The following should be satisfied for all flanking surfaces contained in the measurement volume

$$\overline{L}_{I\text{nM}_\text{s}} - \overline{L}_{I\text{nF}_\text{s}} + 10\ \lg\left[\frac{S_\text{M}}{S_\text{F}}\right] > 10\ \text{dB} \tag{C.1}$$

where

S_F is the area of portion of the flanking surface contained in the measurement volume;

S_M is defined by Equation (7).

If this condition is not achieved, then the portion of the flanking surface contained in the measurement volume should be shielded. In most instances adequate shielding may be achieved by using 13 mm gypsum board placed over 50 mm of fibrous sound absorbing material. Edges and joints of the shielding contained in the measurement volume should be taped to avoid unwanted absorption. After shielding the surface(s), the test should be repeated to ensure the effectiveness of the applied treatment(s).

C.3 Flanking sound reduction index

This part of ISO 15186 may be used to measure and rank the flanking sound reduction index for specific transmission paths in the field or in a flanking laboratory. These measurements may be used to provide guidance in choosing which path(s) should be treated to improve the apparent sound insulation as well as to validate flanking prediction models (such as EN 12354-1).

The relative importance of each room surface in determining the apparent sound insulation may be assessed by simply comparing the sound power radiated by each surface, that is the product of the surface average normal intensity [Equation (18)] and the area of measurement surface [Equation (19)].

Unless special treatments have been made to the source room surface(s) to remove specific paths, the measured sound power is the result of many paths. Figure C.1 shows that if receivng room surface f is measured, then the resulting sound power is due to at least two flanking paths, F-f and D-f. The intensity sound reduction index for the flanking surface f is given by Equation (10).

From Figure C.1 it can be seen that in order to isolate the path F-f, and obtain an estimate of the flanking sound reduction index of this path, the source side of the partition, D, would have to be shielded. Similarly, to obtain the other path, the source surface F would have to be shielded. When used in conjunction with appropriately chosen shielding, Equation (10) may be used to obtain estimates of the flanking sound reduction index for specific paths.

C.4 Relating the modified apparent intensity sound reduction index to ISO 140-4 measures

Often the ISO 140-4 method will be conducted so that the transmission between two rooms and the reported apparent sound reduction index include contributions from the direct and all flanking paths (i.e. none of the source or receiving room surfaces were shielded to suppress flanking transmission). To obtain a similar estimate using the method of this part of ISO 15186, it is necessary to obtain intensity estimates for the partition and all flanking surfaces as indicated in Equation (C.2),

$$R'_I = \left[L_{p1} - 6 + 10\ \lg\left(\frac{S}{S_0}\right)\right] - 10\ \lg\left[\sum_j S_{\text{M}j}\, 10^{0{,}1\overline{L}_{I\text{n}j}}\right] + K_\text{c} \tag{C.2}$$

where the index of summation, j, includes all receive room surfaces. This can be compared directly to the R' result of ISO 140-4 that is obtained when the surfaces are not shielded.

Conversely, if all flanking paths in the source room are suppressed through the use of shielding, and the measurement surface is constructed to enclose only the nominally separating element, then the apparent intensity sound reduction index may approach the sound reduction index obtained from ISO 140-3. It should be noted that differences in damping and edge conditions that may occur for *in-situ* measurements will tend to complicate any comparison.

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 9614-1:1993, *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 1: Measurement at discrete points*

[3] ISO 9614-2:1996, *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 2: Measurement by scanning*

[4] ISO 9614-3:2002, *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 3: Precision method for measurement by scanning*

[5] EN 12354-1, *Building acoustics — Estimation of acoustic performance of buildings from the performance of elements — Part 1: Airborne sound insulation between rooms*

[6] JONASSON, H.G. Sound intensity and sound reduction index. *Applied Acoustics*, **40**, 1993, pp. 281-289

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