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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

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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, $\overline{I}_n$ 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

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

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 $\vec{n}$

$$I_{\mathrm{n}} = \vec{I} \cdot \vec{n} \tag{2}$$

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

3.5
normal sound intensity level
$L_{I\mathrm{n}}$
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

$$L_{I_{\mathrm{n}}} = 10 \lg \frac{|I_{\mathrm{n}}|}{I_0} \tag{3}$$

where

$I_0 = 10^{-12}$ W/m²

3.6
surface pressure-intensity indicator
$F_{pI_{\mathrm{n}}}$
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

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

where

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

and

$$\overline{L}_{I_n} = 10 \lg\left|\frac{1}{S_M}\sum_{i=1}^{N} \frac{S_{M_i}\overline{I}_{n_i}}{I_0}\right| \text{ dB} \tag{6}$$

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

$$S_M = \sum_{i=1}^{N} S_{M_i} \tag{7}$$

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

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

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

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

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

$$R'_I = \left[L_{p1} - 6 + 10 \lg\left(\frac{S}{S_0}\right)\right] - \left[\overline{L}_{I_n} + 10 \lg\left(\frac{S_M}{S_0}\right)\right] \tag{10}$$

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;

$\overline{L}_{I_n}$ 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 m²

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

$\boldsymbol{R_{I\,F\,j}}$

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

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

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;

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

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

S_0 = 1 m²

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

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

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

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

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

$$R'_{I\,m} = R'_I + K_c \tag{14}$$

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.

