INTERNATIONAL STANDARD

ISO 15186-1

First edition
2000-03-01

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

Part 1:
Laboratory measurements

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

Partie 1: Mesurages en laboratoire

Reference number
ISO 15186-1:2000(E)

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Printed in Switzerland

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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 3.

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 part of ISO 15186 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 15186-1 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*

Annexes A and B of this part of ISO 15186 are for information only.

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

Part 1:
Laboratory measurements

1 Scope

This part of ISO 15186 specifies a sound intensity method to determine the sound reduction index and the element-normalized level difference of building elements. The method can be used as an alternative to ISO 140-3 and ISO 140-10 respectively. One important use is when the traditional ISO 140-3 method fails because of high flanking transmission.

The reproducibility of this intensity method is estimated to be equal to or better than that of ISO 140-3.

NOTE Some information about the accuracy with which this part of ISO 15186 can reproduce the sound reduction index measured according to ISO 140-3 is given in annex A.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 15186. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 15186 are encouraged to investigate the possibility of applying the most recent edition of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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

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

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

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

IEC 60942, *Sound calibrators.*

IEC 61043, *Electroacoustics — Instruments for the measurement of sound intensity — Measurement with pairs of pressure sensing microphones.*

3 Terms and definitions

For the purposes of this part of ISO 15186, the following terms and definitions apply.

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, 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 For a complete definition, see ISO 140-3.

3.2
sound reduction index
R
ten times the logarithm to the base 10 of the ratio of the sound power W_1 incident on the test specimen to the sound power W_2 transmitted through the specimen

$$R = 10\,\lg\left(\frac{W_1}{W_2}\right)\,\text{dB} \tag{1}$$

NOTE The expression "sound transmission loss" is also in use.

3.3
sound intensity
I
time-averaged rate of flow of sound energy per unit area oriented normal to the local particle velocity; this is a vectorial quantity which is equal to

$$\vec{I} = \frac{1}{T}\int_0^T p(t)\cdot\vec{u}(t)\cdot\mathrm{d}t \tag{2}$$

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 Sound intensity is measured in watts per square metre.

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

$$I_\mathrm{n} = \vec{I}\cdot\vec{n} \tag{3}$$

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:

$$L_{In} = 10 \lg \frac{I_n}{I_0} \text{ dB} \tag{4}$$

where $I_0 = 10^{-12}$ W/m^2

3.6
surface pressure-intensity indicator
F_p
difference between the sound pressure level, L_p, and the normal sound intensity level, L_{In}, on the measurement surface, both being time and surface averaged:

$$F_{pI} = L_p - L_{In} \tag{5}$$

NOTE This notation is in accordance with ISO 9614-2. In ISO 9614-1 the notation F_2 is used.

3.7
pressure-residual intensity index
δ_{pI0}
difference 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

NOTE 1 It is expressed in decibels.

NOTE 2 Details for determining δ_{pI0} are given in IEC 61043:

$$\delta_{pI0} = \left(L_p - L_I\right) \tag{6}$$

3.8
intensity sound reduction index
R_I
for one source room and one receiving room, which also may be the exterior, this is the index evaluated from equation (1), assuming that the sound field in the source room is diffuse:

$$R_I = L_{p1} - 6 - \left[L_{In} + 10 \lg\left(\frac{S_m}{S}\right)\right] \text{dB} \tag{7}$$

where

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

L_{In} is the average sound intensity level over the measurement surface in the receiving room;

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

S is the area of the test specimen under test.

NOTE The weighted intensity sound reduction index, $R_{I,w}$, is calculated according to ISO 717-1 by replacing R with R_I.

3.9
intensity element normalized level difference
$D_{I,n,e}$
difference given by:

$$D_{I,n,e} = L_{p1} - 6 - \left(L_{In} + 10 \lg\left(\frac{S_m}{A_0}\right) + 10 \lg(N)\right) \text{dB} \tag{8}$$

where

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

L_{In} is the average sound intensity level over the measurement surface in the receiving room;

N is the number of small building element units installed within the measurement surface;

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

A_0 = 10 m^2.

NOTE The weighted intensity element normalized level difference, $D_{I,n,e,w}$, is calculated according to ISO 717-1 by replacing $D_{n,e}$ with $D_{I,n,e}$.

3.10
modified intensity sound reduction index
$R_{I,M}$
index given by:

$$R_{I,M} = R_I + K_c \tag{9}$$

where the values of the adaption term K_c are given in annex B

NOTE 1 In theory the sound reduction index determined using the traditional measurement method (ISO 140-3) is overestimated due to the fact that the sound power radiated into the receiving room is underestimated. To account for this fact, if the aim of the intensity measurements is to simulate measurements according to ISO 140-3, the intensity sound reduction index should be modified as above.

NOTE 2 The weighted modified intensity sound reduction index, $R_{I,M,w,}$ is calculated according to ISO 717-1 by replacing R with $R_{I,M}$. The notation for $R_{I,n,e,M,w}$ is correspondingly obtained.

3.11
measurement surface
surface totally enclosing the test specimen on the receiving side, scanned or sampled by the probe during the measurements

3.12
measurement distance
d
distance between the measurement surface and the specimen in a direction normal to the specimen

3.13
measurement subarea
part of the measurement surface being measured with the intensity probe using one continuous scan or discrete positions

4 Instrumentation

4.1 General

The intensity measuring instrumentation shall be able to measure intensity levels (ref. 10^{-12} W/m^2) in decibels 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 IEC 61043 class 1.

The pressure-residual intensity index δ_{pI0} of the microphone probe and analyser shall be higher than F_{pI} + 10 dB.

NOTE 1 In order to cover the full frequency range, different spacers may be required. The optimum combination of spacer and frequency band will depend on δ_{pI0} and F_{pI}.

As an example the following rule could apply:

a) use a 50 mm spacer between 50 Hz and 500 Hz;

b) use a 12 mm spacer above 500 Hz. The frequency response will usually have to be corrected above 2 000 Hz.

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 140-3. In addition the microphone in the source room shall give a flat frequency response in a diffuse sound field.

NOTE 2 An IEC type WS2P measurement microphone will normally yield a satisfactory frequency response.

4.2 Calibration

It is necessary to verify compliance 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 check that an instrument which has undergone type test and verification is still operating correctly.

a) Allow the instrument to warm up according to the manufacturer's instructions.

b) Set the instrument to the sound pressure mode and apply a class 0 or 1 or 0L or 1L sound pressure calibrator in accordance with IEC 60942 to the two microphones in turn or simultaneously and adjust the instrument to the correct sound pressure indication in both channels.

c) Apply the residual intensity testing device to the two microphones and measure the pressure-residual intensity index 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 check the sound intensity indication.

5 Test arrangement

5.1 Rooms and test opening

The source room and the test opening shall meet the requirements of ISO 140-1. The receiving room may be any room meeting the requirements of the field indicator, F_{pI}, and the background noise; see 6.4.2 and 6.5 respectively.

5.2 Test specimens

The test specimen shall meet the requirements of ISO 140-3 or, for small building elements, ISO 140-10.

5.3 Mounting conditions

Mount the test specimen according to the requirements of ISO 140-3 or, for small building elements, according to ISO 140-10. If one side is sound absorbing, mount this side towards the source room.

6 Test procedure

6.1 General

Measure the average sound pressure level in the source room and the average sound intensity level on a measurement surface in the receiving room. Provided that the sound field pressure-intensity indicator is satisfactory, calculate then the intensity sound reduction index or, alternatively, the intensity element-normalized level difference.

6.2 Generation of sound field

Loudspeaker, noise and loudspeaker positions shall meet the requirements of ISO 140-3.

6.3 Measurement of the 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 140-3.

6.4 Measurement of average sound intensity level on the receiving side

6.4.1 Measurement surface

On the receiving side, use a measurement surface totally enclosing the test specimen. If the test specimen is mounted in a niche, the measurement surface is normally the flat surface of the niche opening. If the test specimen 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. This will be the most common condition for small building elements.

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

Initially select a measurement distance, normally 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 very often. The sound field is also normally more uniform in the niche opening than inside the niche. When using box-shaped measurement surfaces, avoid measurement distances longer than 0,3 m.

6.4.2 Qualification of the measurement surface

Measure the time and space integrated sound intensity level L_{In}. If possible measure the time and space integrated sound pressure level L_p simultaneously. Then calculate the surface pressure-intensity indicator from:

$$F_{pI} = L_p - L_{In} \text{ dB} \qquad (10)$$

If the measured intensity is negative or if F_{pI} is not satisfactory (i.e. if $F_{pI} > 10$ dB for a sound reflecting test specimen, or if $F_{pI} > 6$ dB for a test specimen with a sound absorbing surface in the receiving room), improve the measurement environment. First try to increase the measurement distance by 5 cm to 10 cm. If this fails, add sound absorbing material to the receiving room. For scanning, the sound field indicator requirement is valid for each scan and each loudspeaker position. However, it is only valid for the total measurement surface and not for individual measurement subareas. For discrete positions it is valid for the surface average.

NOTE As a rule of thumb, $F_{pI} < 10$ dB requires

$S/A < 1{,}25$

where

S is the area of the measurement surface;

A is the sound absorption area of the receiving room (for definition, see ISO 140-3); the greater the flanking transmission the more A should be increased.

6.4.3 Scanning procedure

Always hold the probe normal to the measurement surface while scanning and direct it to measure the positive intensity outwards from the building element under test.

The measurement surface may consist of one area or several subareas. The scanning time of each subarea 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 subarea to another. Avoid other stops.

Scan each area or subarea using parallel lines, turning at each edge as shown in Figure 1. The required scanning line density depends on how irregular the sound radiation is. A large amount of irregularities such as leakages requires a higher line density. Normally select the line distance between scan lines to equal the linear measurement distance.

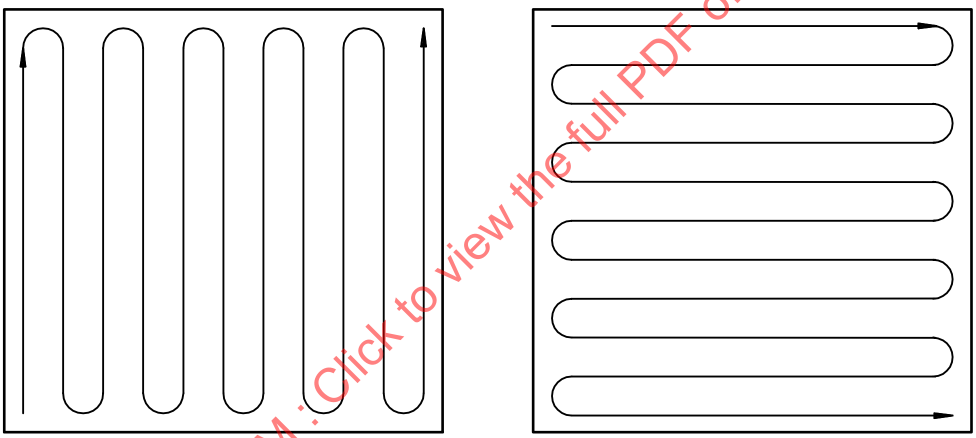

Figure 1 — Scanning patterns for the two scans.

If the measurement surface is box shaped as shown in Figure 2, 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 wall in which the test specimen is mounted. Attempts shall be made to ensure that all the radiated sound intensity is measured by scanning the measurement surface properly. In particular, scan as close as possible to the partition wall.

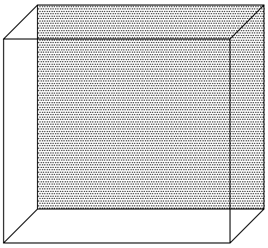

Figure 2 — Box-shaped measurement surface enclosing the test object (shaded area)

6.4.4 Procedure using discrete positions

As an alternative to scanning, fixed positions can be used on the measurement surface described in 6.4.3. Initially select the distance between probe positions to be approximately d m, where d is the measurement distance from the test object. For test specimens having 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. Check the adequacy of the chosen array of measurements positions using annex B of ISO 9614-1:1993. Measure at least 10 s in each probe position. If a moving loudspeaker is used, the minimum number of loudspeaker traverses, for the complete set of microphone positions, shall be two for doors, windows and small building elements, and eight for walls.

6.4.5 Scanning procedure for one measurement area

For each fixed loudspeaker position, once the measurement environment is satisfactory, carry out two complete scans, one for each pattern, and compare the results. Turn the scanning path 90° between the two scans. If the difference between the two measurements is less than 1,0 dB for any one frequency band, the measurement result is given by the arithmetic average of the two measurements. If the difference is larger than 1,0 dB, the measurements are not valid.

Repeat the two scanning patterns until the requirement is fulfilled. If the requirement cannot be fulfilled, change the scanning line density, measurement surface or measurement environment and repeat the measurements 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 provided that all deviations from the requirements of this method are clearly stated.

If two or more loudspeaker positions are used, carry out a pair of scans for each loudspeaker position. Each pair of scans shall comply with the requirements above. Give all results, including the sound reduction index and field indicator, as the arithmetic mean of all scans carried out.

If a moving loudspeaker is used, use, for each scan, at least one loudspeaker traverse for doors, windows and small building elements, and at least two for walls. Scan the measurement surface using the two different scanning patterns. Each of these scans shall take place during a single complete loudspeaker traverse. Select a scan direction to avoid having coinciding loudspeaker/microphone positions in the two scans. The result of each set of patterns is the energy average of the scans. Evaluate the averages of the two patterns as for a fixed loudspeaker position. For each scanning pattern, the total scanning/traverse time shall be at least 120 s for windows, doors and small building elements, and at least 600 s for walls.

6.4.6 Scanning procedure for several measurement subareas

For each subarea, apply the procedures of 6.4.4 or 6.4.5.

If the measurement surface is divided into several subareas, each with the area S_{mi}, each being scanned individually, evaluate the normal sound intensity level L_{In} from:

$$L_{In} = 10 \lg \left[\frac{1}{S_m} \sum_i S_{mi} 10^{0,1 L_{Ini}} \right] \text{dB} \qquad (11)$$

where

i indicates the subarea i;

S_m is the total area measured and is given by

$$S_m = \sum_i S_{mi} \qquad (12)$$

If the sound intensity for a measurement subarea has a negative direction (i.e. if the flow of energy is in the direction towards the test object), a minus-sign shall be inserted before the respective S_{mi} in equation (11).

Calculate the surface pressure-intensity indicator from the following equation:

$$F_{pI} = 10\lg\left[\frac{1}{S_\mathrm{m}}\sum_i S_{\mathrm{m}i} 10^{0,1 L_{pi}}\right]\mathrm{dB} - L_{I\mathrm{n}} \tag{13}$$

where L_{pi} is the the surface-averaged sound pressure level over $S_{\mathrm{m}i}$.

6.5 Background noise

Both the sound pressure level and the sound intensity level shall be at least 10 dB higher than the background noise.

NOTE These requirements may be tested by applying the following procedure.

If the field indicator $F_{pI} < 10$ dB, then lower the source level 10 B. If F_{pI} is changed less than 1 dB, then the requirements are fulfilled.

6.6 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 4 000 5 000

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

Octave band values, if needed, shall be calculated from one-third-octave levels.

NOTE The method given in ISO 15186-3 (in preparation) will yield more accurate results for low frequencies.

7 Expression of results

For the statement of the airborne sound insulation of the test specimen, the intensity sound reduction index R_I shall be given at all frequencies of measurement to one decimal place in a tabular form and/or in the form of a curve, together with the sound field pressure-intensity indicator. For graphs with the level in decibels plotted against frequency on a logarithmic scale, the following dimensions shall be used:

5 mm for one-third octave;

20 mm for 10 dB.

8 Test report

With reference to this part of ISO 15186, 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) Description of the test specimen, including mounting, sealing and mass per unit area.

f) Volume and description of measurement rooms.

g) Area of test object, S, and of measurement surface S_{m}.

h) Intensity sound reduction index as a function of frequency, weighted intensity sound reduction index and, if relevant, modified intensity sound reduction index and modified weighted intensity sound reduction index. If the modified intensity sound reduction index is used, the volume and the boundary surface used for the calculations shall be stated.

NOTE For the evaluation of single number ratings, see ISO 717-1.

i) Surface pressure-intensity indicator, F_{pI}, and pressure-residual intensity index, δ_{pI0} as a function of frequency.

j) Measurement distance and shape and area of measurement surface; description of measurement segments, if more than one.

k) Information regarding the measurement equipment, including probe (microphone diameter, spacings).

l) Information about which test method was used.

Annex A
(informative)

Estimated precision of the method

An example of the estimated precision of the method given in this part of ISO 15186, using the modified intensity sound reduction index, $R_{I,\mathrm{M}}$, with which the sound reduction index R determined according to ISO 140-3 may be reproduced, is given in Table A.1.

The estimates in Table A.1 are based on about 30 comparison measurements carried out in three different Scandinavian laboratories. The receiving rooms were well defined and identical for the two test methods.

Table A.1

Frequency Hz	Average overestimate $(R_{I,\mathrm{M}} - R)$ dB	Standard deviation dB
50	5	6
63 to 80	1,5	3
100	1	2
125 to 400	1	1,5
500 to 1 600	0,5	1,5
2 000 to 3 150	1	2
4 000	1,5	2
5 000	1,5	3
100 to 3 150, R_w	0,5	1

Annex B
(informative)

Adaption term K_c

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

Whenever the traditional measurements according to ISO 140-3 have been taken in a well-defined receiving room:

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

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 midband frequency.

Whenever the traditional measurements according to ISO 140-3 have been taken in a room which is not well defined, K_c is given by Table B.1.

K_c can also be calculated from

$$K_c = 10 \lg \left(1 + \frac{614}{f} \right) \tag{B.2}$$

where f is the the midband frequency of the one-third-octave band.

The values of Table B.1 were calculated based on the following values of the different parameters:

S_{b2} = 117 m^2

V_2 = 81 m^3 (4,5 × 6,0 × 3,0)

The dimensions were selected to be a compromise between two commonly used room sizes in acoustic laboratories: approximately 50 m^3 and 100 m^3.