INTERNATIONAL STANDARD

ISO 11546-1

First edition
1995-12-15

Acoustics — Determination of sound insulation performances of enclosures —

Part 1: Measurements under laboratory conditions (for declaration purposes)

Acoustique — Détermination de l'isolement acoustique des encoffrements —

Partie 1: Mesurages dans des conditions de laboratoire (aux fins de déclaration)

Reference number
ISO 11546-1:1995(E)

Contents

International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland

Printed in Switzerland

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

International Standard ISO 11546-1 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

ISO 11546 consists of the following parts, under the general title *Acoustics — Determination of sound insulation performances of enclosures*:

— *Part 1: Measurements under laboratory conditions (for declaration purposes)*

— *Part 2: Measurements in situ (for acceptance and verification purposes)*

Annex A forms an integral part of this part of ISO 11546. Annexes B, C and D are for information only.

Acoustics — Determination of sound insulation performances of enclosures —

Part 1:
Measurements under laboratory conditions (for declaration purposes)

1 Scope

This part of ISO 11546 specifies laboratory methods for the determination of the sound insulation performance (insertion loss) of small machine enclosures.

It applies to a total enclosure only and not to the individual panels from which the enclosure is made.

NOTES

1 Sound insulation for enclosure panels such as wall elements, doors, windows, silencers, etc. should be measured in accordance with other relevant standards.

2 Related standards concern noise-attenuation measurements of enclosures *in situ* (ISO 11546-2) and cabins (ISO 11957).

The measurement methods specified in this part of ISO 11546 are based on International Standards in the series ISO 3740, ISO 9614 and ISO 11200 (see table 1). Depending on the method chosen, the sound insulation performance (insertion loss) of the enclosure is determined in terms of the reduction of sound power level or sound pressure level. Methods are given for measurements where the enclosure surrounds the actual sound source (machine). Where these methods are not practicable, alternative measurements can be performed using a reciprocity method (see definition 3.11 and subclause 7.2) or an artificial sound source.

This part of ISO 11546 is applicable without any restrictions to freestanding enclosures with volumes less than 2 m^3. If the actual sound source is used, the sound insulation performance of enclosures with volumes exceeding 2 m^3 can be determined provided that the requirements concerning maximum permissible volume in the standard used are fulfilled. The actual sound source method is applicable for any kind of enclosure design, for example enclosures fixed to the machine.

When the reciprocity method or the artificial sound source method is used, the maximum volume of the enclosure is limited to 2 m^3. These methods are not applicable to close-fitting enclosures.

The wording "laboratory conditions" used in the title of this part of ISO 11546 indicates that test conditions and test environment (indoor or outdoor) fully conform to the respective International Standards given in table 1.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 11546. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 11546 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 140-6:1978, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 6: Laboratory measurements of impact sound insulation of floors.*

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

ISO 3741:1988, *Acoustics — Determination of sound power levels of noise sources — Precision methods for broad-band sources in reverberation rooms.*

ISO 3742:1988, *Acoustics — Determination of sound power levels of noise sources — Precision methods for discrete-frequency and narrow-band sources in reverberation rooms.*

ISO 3743-1:1994, *Acoustics — Determination of sound power levels of noise sources — Engineering methods for small, movable sources in reverberant fields — Part 1: Comparison method for hard-walled test rooms.*

ISO 3743-2:1994, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering methods for small, movable sources in reverberant fields — Part 2: Methods for special reverberation test rooms.*

ISO 3744:1994, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering method in an essentially free field over a reflecting plane.*

ISO 4871:—[2], *Acoustics — Declaration and verification of noise emission values of machinery and equipment.*

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

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

ISO 11201:1995, *Acoustics — Noise emitted by machinery and equipment — Measurement of emission sound pressure levels at a work station and at other specified positions — Engineering method in an essentially free field over a reflecting plane.*

ISO 11204:1995, *Acoustics — Noise emitted by machinery and equipment — Measurement of emission sound pressure levels at a work station and at other specified positions — Method requiring environmental corrections.*

IEC 651:1979, *Sound level meters.*

IEC 804:1985, *Integrating-averaging sound level meters.*

IEC 942:1988, *Sound calibrators.*

IEC 1260:—[4], *Electroacoustics — Octave-band and fractional-octave-band filters.*

3 Definitions

For the purposes of this part of ISO 11546, the following definitions apply.

3.1 A-weighting: Frequency weighting as defined in IEC 651.

3.2 enclosure: A structure enveloping a noise source (machine), designed to protect the environment from this noise source (machine).

NOTE 3 An enclosure can be, for example, a freestanding structure terminated on the floor or a structure more or less fixed to the machine. (Concerning enclosures fixed to the machine, see clause 4.)

3.3 sound pressure level, L_p: Ten times the logarithm to the base 10 of the ratio of the square of the sound pressure of a sound to the square of the reference sound pressure. Sound pressure levels are expressed in decibels. The reference sound pressure is 20 µPa (2×10^{-5} Pa).

3.4 average sound pressure level, $\bar{L}_p$: Mean-square of the sound pressure levels:

$$\bar{L}_p = 10 \lg \left(\frac{10^{0,1L_{p1}} + 10^{0,1L_{p2}} + \ldots + 10^{0,1L_{pn}}}{n} \right) \text{ dB}$$

where L_{p1}, L_{p2}, ..., L_{pn} are the sound pressure levels, in decibels, to be averaged.

1) To be published. (Revision of ISO 717-1:1982 and ISO 717-3:1982)

2) To be published. (Revision of ISO 4871:1984)

3) To be published.

4) To be published. (Revision of IEC 225:1966)

3.5 sound power level, L_W: Ten times the logarithm to the base 10 of the ratio of a given sound power to the reference sound power. It is expressed in decibels. The reference sound power is 1 pW (10^{-12} W).

3.6 average sound power level, $\overline{L}_W$: Mean-square of the sound power levels:

$$\overline{L}_W = 10 \lg \left(\frac{10^{0,1 L_{W1}} + 10^{0,1 L_{W2}} + \ldots + 10^{0,1 L_{Wn}}}{n} \right) \text{dB}$$

where L_{W1}, L_{W2}, ..., L_{Wn} are the sound power levels, in decibels, to be averaged.

3.7 sound power insulation, D_W: Reduction in sound power level obtained due to the enclosure (octave bands or one-third-octave bands). It is expressed in decibels.

3.8 A-weighted sound power insulation, D_{WA}: Reduction in the A-weighted sound power level obtained due to the enclosure for the actual sound source spectrum. It is expressed in decibels.

3.9 sound pressure insulation, D_p: Reduction in the sound pressure level at a specified position due to the enclosure (octave bands or one-third-octave bands). It is expressed in decibels.

3.10 A-weighted sound pressure insulation, D_{pA}: Reduction in A-weighted sound pressure level at a specified position due to the enclosure for the actual sound source spectrum. It is expressed in decibels.

3.11 sound pressure insulation (reciprocity method), D_{pr}: Difference between the averaged sound pressure level in an external diffuse sound field and the averaged sound pressure level inside an enclosure located in this field. It is expressed in decibels.

3.12 estimated noise insulation due to the enclosure, $D_{WA,e}$, $D_{pA,e}$ or $D_{prA,e}$: Calculated reduction in A-weighted sound power or sound pressure level obtained from D_W, D_p or D_{pr}, measured in accordance with this part of ISO 11546, and a specific noise spectrum. (See annex C.) It is expressed in decibels.

3.13 weighted sound pressure insulation (reciprocity method), $D_{pr,w}$: Single-number value determined in accordance with the method stated in ISO 717-1 except that the sound reduction index is replaced by the sound pressure insulation, reciprocity method, D_{pr}. It is expressed in decibels.

3.14 weighted sound power insulation, $D_{W,w}$: Single-number value determined in accordance with the method stated in ISO 717-1 except that the sound reduction index is replaced by the sound power insulation, D_W. It is expressed in decibels.

3.15 fill ratio, ϕ: Ratio of the volume of the source in an enclosure to the interior volume of that enclosure.

In cases where the shape of the source complicates calculation of the source volume, the volume of a reference box determined in accordance with ISO 3744 can be used.

3.16 leak ratio, θ: Ratio between the area of all openings of the enclosure and the total interior surface area of the enclosure (including openings).

NOTES

4 Openings provided with sufficiently efficient sound-attenuating silencers are not regarded as openings with respect to the leak ratio.

5 The reciprocal value of the leak ratio is designated the seal ratio, Ψ ($\Psi = 1/\theta$).

4 Choice of measurement method

Accurate values of the sound insulation performance of an enclosure can only be obtained when the measurements take place with the actual sound source for which the enclosure is designed. Thus, whenever practicable, methods using the real source shall be used. If the enclosure is fixed or otherwise connected to the sound source, the sound insulation performance can only be determined with the actual sound source.

If the actual sound source cannot be used, a reciprocity method using an external sound field to determine the sound insulation performance is the preferred method. In cases where neither the real sound source method nor the reciprocity method are applicable, the sound insulation performance can be obtained using inside the enclosure the artificial sound source described in annex A. These methods are particularly useful when sound insulation data are required for universally usable enclosures with sound-absorbing interior surfaces and small leak ratios (preferably $\theta < 2$ %). The reciprocity method and the artificial sound source method are applicable to enclosures with volumes less than 2 m^3.

NOTE 6 The more the enclosure deviates from these ideal conditions regarding the leak ratio and absorption, the more there is a need to take measurements using the actual sound source. The reciprocity method and the artificial sound source method are not applicable to close-fitting enclosures (covers and cladding) where there is no free vol-

ume between the enclosure and the surface of the actual sound source.

In cases where a single-number value is wanted based on measurements carried out with the reciprocity method or the artificial sound source method, the weighted sound pressure insulation, $D_{pr,w}$, and the weighted sound power insulation, $D_{W,w}$, are the preferred quantities. (See definitions 3.13 and 3.14.) The weighted sound insulation is a practicable single-number value to be used for a rough comparison of different enclosures. However, this quantity must not be taken as a general measure of the sound insulation performance of the enclosure, as the performance in actual situations strongly depends on the spectrum of the actual noise.

If the actual noise is known or can be assumed, the reduction in A-weighted noise level due to the enclosure can be estimated according to the method given in annex C.

NOTE 7 Measurement data obtained using the actual sound source are not necessarily comparable with data obtained using the reciprocity method or an artificial sound source. In cases where the actual sound source is connected to the enclosure, structure-borne sound may influence the measurement result.

This part of ISO 11546 is intended for use together with a relevant International Standard for the determination of sound power level or measurement of sound pressure level. The applicability of the different methods described is summarized in table 1.

Table 1 — Applicability of the different test methods

Test method	Test environment	International Standard	Symbol[1]	Sub-clause
Actual sound source	Reverberation room	ISO 3741 ISO 3742	D_W, D_{WA}	6.1 6.2
	Hard-walled test room	ISO 3743-1	D_W, D_{WA}	
	Special reverberation room	ISO 3743-2	D_W, D_{WA}	
	Outdoors or in large room	ISO 3744	D_W, D_{WA}	
	No special test environment	ISO 9614-1[2] ISO 9614-2	D_W, D_{WA}	
	Free-field over a reflecting plane; indoor or outdoor	ISO 11201	D_p, D_{pA}	6.1 6.3
	Outdoors or in large room	ISO 11204[2]	D_p, D_{pA}	
Reciprocity	Reverberation room	Test room complying with ISO 3741	D_{pr}, $D_{pr,w}$	7.1 7.2 7.4
Artificial sound source	Reverberation room	ISO 3741	D_W, $D_{W,w}$	7.1 7.3 7.4
	Hard-walled test room	ISO 3743-1	D_W, $D_{W,w}$	
	Special reverberation room	ISO 3743-2	D_W, $D_{W,w}$	
	Outdoors or in large room	ISO 3744	D_W, $D_{W,w}$	
	No special test environment	ISO 9614-1[2] ISO 9614-2	D_W, $D_{W,w}$	
	Free-field over a reflecting plane; indoor or outdoor	ISO 11201	D_p	
	Outdoors or in large room	ISO 11204[2]	D_p	

1) Notation according to clause 3.

2) Grade 3 methods (survey) are not applicable when using this part of ISO 11546.

5 Instrumentation

The instrumentation system, including the microphones and cables, shall meet the requirements for a type 1 instrument as specified in IEC 651 or, in the case of integrating-averaging sound level meters, the requirements for a type 1 instrument as specified in IEC 804.

NOTE 8 Generally, an integrating-averaging sound level meter is preferred.

For measurements in octave or one-third-octave bands, the instrumentation system shall meet the requirements for a type 1 filter as specified in IEC 1260.

Before and after each series of measurements, the calibration of the entire measuring system shall be verified using an acoustical calibrator with an accuracy of $\pm$ 0,3 dB (type 1 in accordance with IEC 942).

NOTE 9 An equivalent verification method which has been proved to be capable of checking the stability of the measurement system may be used.

6 Test methods applicable to enclosures with the actual sound source

6.1 General

6.1.1 When applying the actual sound source method, the maximum permissible volume of the enclosure is given by the relevant International Standard, selected from table 1.

6.1.2 The operating conditions of the actual sound source shall be representative of normal use and shall not change between the measurements made with and without the enclosure. If a special test code exists for the actual sound source, the operating conditions specified in such a test code shall be used.

6.1.3 If the enclosure includes active elements (e.g. fans), these elements shall be in operation during the measurements. If the active elements are not intended for continuous operation, measurement shall be carried out both with the active elements switched on and switched off.

6.1.4 When measuring in a reverberation room, place the enclosure in such a way that no enclosure wall is parallel to any wall of the room. The minimum distance from the enclosure to any wall shall be 1,5 m.

6.1.5 If practicable, choose the microphone positions to give the same environmental corrections both with and without the enclosure. When measuring with the enclosure, the test object is defined to be the machine with the enclosure. The microphone positions used for measurements on the enclosed source shall, if practicable, be the same as those used for the unenclosed source.

NOTE 10 When measurements are carried out on enclosures with high sound insulation, care should be taken to ensure that structure-borne sound/vibration in the floor of the test room does not influence the measurement result.

6.2 Determination of sound power insulation

One of the International Standards ISO 3741, ISO 3742, ISO 3743-1, ISO 3743-2, ISO 3744, ISO 9614-1 or ISO 9614-2 shall be chosen depending on the test environment.

Determine the time-averaged sound power level during a typical operational cycle of the machine.

Make the measurements with and without the enclosure. The sound power insulation in octave or one-third-octave bands (D_W) and A-weighted (D_{WA}) are given by:

$$D_W = L_W(\text{without enclosure}) - L_W(\text{with enclosure}) \quad \dots (1)$$

$$D_{WA} = L_{WA}(\text{without enclosure}) - L_{WA}(\text{with enclosure}) \quad \dots (2)$$

where

L_W is the sound power level, in decibels, in octave or one-third-octave bands measured in accordance with the relevant International Standard;

L_{WA} is the A-weighted sound power level, in decibels, measured or calculated in accordance with the relevant International Standard.

The frequency range shall at least cover the range 100 Hz to 5 000 Hz for one-third-octave bands and 125 Hz to 4 000 Hz for octave bands.

NOTE 11 Frequency ranges of 50 Hz to 10 000 Hz for one-third-octave bands and 63 Hz to 8 000 Hz for octave bands are preferred.

The A-weighted levels are calculated from the band pressure levels when ISO 3741, ISO 3742, ISO 3743-1, ISO 9614-1 and ISO 9614-2 are used. According to ISO 3743-2, the A-weighted levels can be measured directly. According to ISO 3744, the A-weighted levels can be measured or calculated from frequency band data.

NOTE 12 In order to ensure consistency between frequency band data and the A-weighted value, use of the calculated A-weighted value is preferred.

Provided that the test environments and microphone positions are identical for measurements with and without the enclosure, the sound power level difference is equal to the sound pressure level difference averaged according to the chosen International Standard. This means that under identical test conditions (i.e. identical environmental corrections) it is not necessary to convert the measured sound pressure levels into sound power levels before calculating the difference in levels. If the measurements with and without the enclosure cannot be carried out within a very short period of time under fully controlled and identical test conditions, the sound power levels shall be determined.

6.3 Determination of sound pressure insulation at a specified position

Make the measurements as specified in ISO 11201 or ISO 11204. Determine the time-averaged sound pressure level during a typical operational cycle of the machine.

The sound pressure insulation in octave or one-third-octave bands (D_p) and A-weighted (D_{pA}) are given by:

$$D_p = L_p(\text{without enclosure}) - L_p(\text{with enclosure}) \quad \ldots (3)$$

$$D_{pA} = L_{pA}(\text{without enclosure}) - L_{pA}(\text{with enclosure}) \quad \ldots (4)$$

where

L_p is the sound pressure level, in decibels, in octave or one-third-octave bands at a specified position measured in accordance with the relevant International Standard;

L_{pA} is the A-weighted sound pressure level, in decibels, at a specified position measured or calculated in accordance with the relevant International Standard.

Use the frequency range as given in 6.2. According to ISO 11201 and ISO 11204, A-weighted values can be measured directly or calculated from frequency band data.

NOTE 13 In order to ensure consistency between frequency band data and the A-weighted value, use of the calculated A-weighted value is preferred.

7 Test methods applicable to enclosures without the actual sound source

7.1 General

If the actual sound source method cannot be used, the reciprocity method is the preferred one. In cases where neither the actual sound source method nor the reciprocity method is applicable, use an artificial sound source as described in annex A.

The reciprocity method and the artificial sound source method are applicable to enclosures with volumes of less than 2 m^3. The methods are especially intended for universally applicable enclosures, i.e. enclosures not designed for one type of source only.

If the enclosure includes active elements (e.g. fans), neither the artificial sound source method nor the reciprocity method can be used.

NOTE 14 Enclosures with a small leak ratio ($\theta < 2$ %) and with sound-absorbing interior surfaces are particularly suitable for measurements with the reciprocity method or the artificial sound source method.

7.2 Reciprocity method

The test environment shall comply with the requirements for reverberation rooms given in ISO 3741. A reverberant sound field is generated in the room and the sound pressure level difference between the room and the inside of the enclosure is determined.

Place the enclosure asymmetrically on the floor in such a way that no enclosure wall is parallel to any wall of the test room. For measurements in the frequency range 100 Hz to 10 000 Hz, the distance between the enclosure and the walls and ceiling of the room shall be at least one-half of the wavelength corresponding to the centre frequency of the lowest frequency band of interest. Furthermore, the distance between the enclosure and any diffusing elements in the room shall be at least one-half of a wavelength. For measurements in the frequency range 50 Hz to 80 Hz, the distance shall be at least 2 m.

The enclosure shall be present in the room during all measurements.

The sound field shall be generated by at least two loudspeakers driven at the same time by independent generators (or sequentially by one loudspeaker in at least two positions). The distance between the loudspeaker positions shall be at least 3 m. The distance between any loudspeaker position and the enclosure shall be as great as possible and at least 2 m. The distance between the loudspeakers and any microphone position shall be at least 2 m.

The minimum distance of 2 m assumes that the loudspeaker is omnidirectional. If this is not the case or if the loudspeaker is placed close to a corner of the room, the minimum distance should be increased. The radiation pattern of the loudspeaker shall be as non-directional as possible.

The generated sound shall be steady and have a continuous spectrum in the frequency band considered. If the measurement is carried out using octave bands, the spectrum shall be approximately flat within each octave band.

For each loudspeaker position, the octave or one-third-octave band sound pressure levels in the room shall be measured in at least six fixed microphone positions distributed evenly around/above the enclosure. The procedures of ISO 3741:1988, clause 7 shall be followed. The requirements given in subclause 7.1.3 of ISO 3741:1988 concerning the distance between microphone positions and room surfaces are also valid for the distances between microphone positions and the exterior surface of the enclosure.

For each loudspeaker position, determine the average sound pressure level in the enclosure by averaging values obtained inside a volume smaller than the enclosure volume but with the same shape. The limiting surfaces of this averaging volume shall be at the distance $0{,}2d$ from the interior surfaces of the enclosure, where d is the shortest inner dimension. At least six discrete microphone positions, or one sweeping microphone covering a substantial proportion of the volume, shall be used.

The average sound pressure level obtained with different loudspeaker positions as well as with different microphone positions shall be determined as an average value on a mean-square basis.

The frequency range shall be at least cover the range 100 Hz to 5 000 Hz for one-third-octave bands and 125 Hz to 4 000 Hz for octave bands.

NOTE 15 Frequency ranges of 50 Hz to 10 000 Hz for one-third-octave bands and 63 Hz to 8 000 Hz for octave bands are preferred.

The sound pressure insulation (reciprocity method), is given by:

$$D_{pr} = \bar{L}_p(\text{room}) - \bar{L}_p(\text{enclosure}) \quad \ldots (5)$$

where

$\bar{L}_p$(room) is the averaged sound pressure level, in decibels, in the room;

$\bar{L}_p$(enclosure) is the averaged sound pressure level, in decibels, inside the enclosure.

7.3 Artificial sound source method

The artificial sound source shall be constructed as shown in annex A. The fill ratio (3.15) shall not exceed 25 %. The sound power output shall be sufficient to give a sound pressure level outside the enclosure so that requirements regarding background noise in the International Standard used are fulfilled. Background noise corrections shall be made as indicated in that International Standard.

NOTE 16 The artificial sound source has an essentially downwards sound radiation which implies that the surface supporting the sound source will be excited strongly. This should be kept in mind especially in cases where a lightweight wooden floor is an integrated part of the enclosure. The near-field influence from the sound source may lead to an increased sound radiation from the other surfaces of the enclosure due to contribution of structure-borne sound from the floor.

For measurements on enclosures without an integrated floor, there might be a risk of flanking transmission in the floor of the test room. Attention should be especially drawn to this if the floor of the test room is a lightweight wooden or concrete type.

The degree of near-field influence can be estimated by comparing results from measurements with the sound source placed on the floor and raised from the floor, respectively. (See annex A.) If a significant difference between these test results is observed, the near-field influence is essential, and the placement of the sound source must be considered very carefully regarding the position of the actual sound source.

Make measurements with an artificial sound source in one-third-octave or octave bands and as specified in 6.1, 6.2 and 6.3.

In the case of a cubic or quasicubic enclosure, the artificial sound source shall be placed on the floor near the centre of the enclosure or at the position planned for the actual sound source.

In the case of an enclosure with a rectangular base, the artificial sound source shall be placed on the floor