INTERNATIONAL STANDARD

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Acoustics — Determination of sound insulation performance of cabins — Laboratory and *in situ* measurements

Acoustique — Détermination des performances d'isolation acoustique des cabines — Mesurages en laboratoire et in situ

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Contents

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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 lialison 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 11957 was prepared by Technical Committee ISO/TC 43, *Acoustics,* Subcommittee SC 1, *Noise,* on request from CEN/TC 211, *Acoustics.*

Related standards concern noise attenuation measurements of enclosures under laboratory conditions (ISO 11546-1) and *in situ* (ISO 11546-2).

Annexes A and B of this International Standard are for information only.

Acoustics — Determination of sound insulation performance of cabins — Laboratory and *in situ* measurements

1 Scope

This International Standard specifies a laboratory method (clause 6) and *in situ* methods (clause 7) for the determination of the sound insulation performance of sound-protecting cabins. The sound insulation performance is the reduction in sound pressure level or sound power level afforded by the cabin. The methods are applicable to cabins with a small leak ratio ($\theta \leqslant 2$ %).

This International Standard is applicable to a complete cabin only and not to the individual components from which it is made.

NOTE 1 Sound insulations for cabin components such as wall elements, doors, windows, silencers, etc. should be measured according to other relevant standards.

Requirements for the test environment in the laboratory are based on those given in ISO 3741.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard 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 717-1:—[1], *Acoustics — Rating of sound insulation in buildings and of building elements — Part 1: Airborne sound insulation.*

ISO 3741: —[2], *Acoustics — Determination of sound power levels of noise sources using sound pressure — Precision methods for reverberation rooms.*

ISO 4871:1996, *Acoustics — Declaration and verification of noise emission values of machinery and equipment.*

IEC 651:1979, *Sound level meters.*

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

IEC 942:1988, *Sound calibrators.*

IEC 1260:1995, *Electroacoustics — Octave-band and fractional-octave-band filters.*

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 A-weighting: Frequency weighting in accordance with IEC 651.

3.2 cabin: An enclosure specially designed to shield human beings from environmental noise.

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

2) To be published. (Revision of ISO 3741:1988 and ISO 3742:1988)

3.3 sound pressure level, L_p: Ten times the logarithm to the base 10 of the ratio of the mean-square sound pressure to the square of the reference sound pressure (= 20 µPa). It is expressed in decibels.

3.4 average sound pressure level (on a mean-square basis), $\overline{L_p}$:

$$\overline{L_p} = 10 \lg \left(\frac{10^{0,1\, L_{p1}} + 10^{0,1\, L_{p2}} + ... + 10^{0,1\, L_{pn}}}{n} \right) \text{dB}$$

where

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

n is the number of values to be averaged.

It is expressed in decibels.

3.5 sound pressure insulation, D_p: Difference, in one-third-octave or octave bands, between the sound pressure level of an external reverberant sound field and the sound pressure level inside a cabin located in this field. It is expressed in decibels.

3.6 apparent sound pressure insulation, D'_p: Difference, in one-third-octave or octave bands, between the sound pressure level in a room and the sound pressure level in a cabin located in the room. It is expressed in decibels. The sound field in the room need not necessarily be diffuse.

NOTE 2 The word "apparent" indicates that the measurement has been carried out under *in situ* conditions.

3.7 apparent A-weighted sound pressure insulation, D'_{pA}: Difference in A-weighted sound pressure levels measured in the room and in the cabin, respectively, when the actual environmental noise is used as the sound source. It is expressed in decibels. (See note 2.)

3.8 weighted sound pressure insulation, $D_{p,w}$: Single-number value determined in accordance with the method stated in ISO 717-1. It is expressed in decibels. However, the sound reduction index used in ISO 717-1 is replaced by the sound pressure insulation, D_p. (See clause 8.)

3.9 apparent weighted sound pressure insulation, $D'_{p,w}$: Single-number value determined in accordance with the method stated in ISO 717-1. It is expressed in decibels. However, the sound reduction index used in ISO 717-1 is replaced by the apparent sound pressure insulation, D'_p. (See note 2 and clause 8.)

3.10 estimated cabin noise insulation, $D_{pA,e}$: Calculated reduction in A-weighted sound pressure level for a specific spectrum (the actual noise), obtained from D_p measured in accordance with this International Standard. It is expressed in decibels. (See annex A.)

3.11 apparent estimated cabin noise insulation, $D'_{pA,e}$: Calculated reduction in A-weighted sound pressure level for a specific spectrum (the actual noise), obtained from D'_p measured in accordance with this International Standard. It is expressed in decibels. (See note 2 and annex A.)

3.12 internal noise level, L_{pA}: A-weighted average sound pressure level inside the cabin caused by sound sources which are an integrated part of the cabin. It is expressed in decibels.

3.13 background noise level: Averaged sound pressure level inside or outside the cabin when the loudspeakers, the actual environmental noise and the sound sources which are an integrated part of the cabin are switched off. It is expressed in decibels.

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

NOTES

3 The reciprocal value of the leak ratio is designated the seal ratio, ψ ($\psi = 1/\theta$).

4 Openings provided with sufficiently effective silencers are not regarded as openings in this context.

3.15 empty cabin: Normally equipped cabin with no human beings inside.

3.16 reverberant sound field: That portion of the sound field in the test room where the influence of sound received directly from the source is negligible.

3.17 room: Enclosed space, external to the cabin, where sound is generated.

4 Test environment and choice of suitable quantity

If the test is conducted in a laboratory (clause 6), the test environment shall be a reverberation room as specified in ISO 3741. If the test is conducted *in situ*

(clause 7), no specific requirements concerning the room need be fulfilled. An external sound field generated in the room is used to determine the cabin sound pressure insulation.

Differences can occur between laboratory and *in situ* test results. Therefore, only data based on the same measurement method shall be used when comparing the performance of different cabins.

NOTE 5 The size and volume of the cabin may influence the sound insulation performance. Consequently, it is recommended that only data for cabins of approximately equal sizes be used when comparing the performance of different cabins.

In cases where a single-number value is wanted as a general quantity describing the sound insulation, the weighted sound pressure insulation, $D_{p,w}$, is the preferred quantity. The weighted sound pressure insulation is a practical single-number value to be used for a rough comparison of different cabins. However, this quantity shall not be taken as a general measure of the sound insulation performance of the cabin, as the performance in actual situations strongly depends on the spectrum of the actual noise.

It is possible to calculate approximately the reduction in the A-weighted sound pressure level due to the cabin, using a known spectrum of the environmental noise (the actual noise). (See annex A.)

5 Instrumentation

The instrumentation system, including microphone and cable, 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 6 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 class 1 filter as specified in IEC 1260.

Before and after each series of measurements, the stability and calibration of the entire instrumentation shall be verified at one or more frequencies over the frequency range of interest using an acoustical calibrator of class 1 in accordance with IEC 942.

NOTES

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

8 For measurements carried out *in situ*, class 2 instruments are acceptable.

6 Measurement of sound insulation performance in the laboratory

6.1 General

The test environment shall be a reverberation room complying with the specifications 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 an empty cabin is determined. (See 6.4 to 6.6.)

6.2 Cabin locations

The cabin shall be placed asymmetrically on the floor in such a way that no cabin wall is parallel to any wall of the room.

For measurements in the frequency range from 100 Hz to 10 000 Hz, the distance between the cabin and the walls and ceiling of the room shall be at least one-half wavelength corresponding to the centre frequency of the lowest frequency band of interest. Furthermore, the distance between the cabin and any diffusing elements in the room shall be at least one-half of this wavelength. For measurements in the frequency range from 50 Hz to 80 Hz, the distance shall be at least 2 m.

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

6.3 Cabin mounting and conditions

The cabin shall be installed as specified by the manufacturer.

The cabin shall be empty during the measurements. Unless otherwise specified in the operating instructions for the cabin, the doors and windows shall be closed, noise sources forming an integral part of the cabin such as ventilating fans shall be switched off, and valves or dampers in the ventilation system shall be open when measuring the sound insulation performance. For additional information, the sound insulation performance with the valves closed may be determined. The sound pressure level inside the cabin due to noise sources forming an integral part of the cabin, if any, shall be determined as specified in 6.7. All movable parts of the cabin shall be operated at least 10 times before the measurement is carried out.

For cabins without an integrated floor, there shall be no leaks between the cabin and the floor of the room.

NOTE 9 A high degree of flanking transmission in the floor of the room may influence the measurement result (sound transmission from the room to the cabin through the floor).

6.4 Measurement of the sound pressure level in the room

At least two loudspeaker positions shall be used to generate the sound field in the reverberation room. The measurements can be carried out either sequentially by moving one loudspeaker cabinet between the chosen positions, or several loudspeakers can be operated simultaneously provided that each loudspeaker has a separate noise generator and power amplifier.

The distance between the loudspeaker positions shall be at least 3 m. The distance between any loudspeaker position and the cabin shall be as great as possible and at least 2 m. The distance between the loudspeakers and any microphone positions shall be at least 2 m.

NOTE 10 The minimum distance of 2 m will be sufficient, provided that the loudspeaker is approximately omnidirectional and that loudspeaker positions close to room surfaces or corners are avoided.

The generated sound shall be steady and have a continuous spectrum in the frequency range considered. If the measurement is carried out using octave bands, the spectrum shall be approximately flat within each octave band. The three one-third-octave band levels within each octave band shall not differ by more than 6 dB in the octave band of 125 Hz, 5 dB in the band of 250 Hz, and 4 dB in the bands of higher frequencies. The output shall be sufficiently high to give a sound pressure level inside the cabin exceeding the background noise level by at least 6 dB, and preferably by more than 12 dB for all frequency bands of interest. Correction for the influence of background noise inside the cabin shall be carried out in accordance with ISO 3741.

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

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

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

The average sound pressure level over different loudspeaker positions in the reverberation room shall be determined as an average value on a mean-square basis.

6.5 Measurement of the sound pressure level inside the cabin

6.5.1 Without a well-defined operator's position

No microphone position shall be closer to the internal cabin surfaces than 0,2 d, where d is the shortest inner dimension of the cabin. All positions shall be at least 1 m above floor level.

The sound pressure level for each loudspeaker position shall be measured in at least six fixed microphone positions or by use of a rotating microphone. Fixed microphones shall be distributed over the entire allowable volume as defined above. If a rotating microphone is used, the path shall cover a substantial portion of the allowable volume.

The measured sound pressure levels in the different microphone positions shall be averaged on a mean-square basis.

6.5.2 With a well-defined operator's position

For cabins with only one well-defined operator's position, the averaging volume is defined by the volume containing typical ear positions of an operator. If fixed microphones are used, three positions shall be distributed on a sphere with a radius of 0,3 m and the centre at the head-position of the operator. If a rotating microphone is used, the radius shall be 0,3 m and the centre of the circle shall be at the head-position of the operator. The path shall be inclined by 45° relative to the horizontal plane.

The measured sound pressure levels in the different microphone positions shall be averaged on a mean-square basis.

6.6 Sound pressure insulation, D_p

The sound pressure insulation in one-third-octave or octave bands, D_p, is given by

$$D_p = (L_p)_{\text{room}} - (L_p)_{\text{cabin}} \quad \ldots (1)$$

where

$(L_p)_{\text{room}}$ is the averaged sound pressure level, in decibels, in one-third-octave or octave bands in the room;

$(L_p)_{cabin}$ is the averaged sound pressure level, in decibels, in one-third-octave or octave bands inside the cabin.

6.7 Measurement of noise inside the cabin due to noise sources forming an integral part of the cabin
(internal noise level, L_{pA})

If the cabin includes noise sources (e.g. fans) installed as an integral part of the cabin, the A-weighted sound pressure level inside the cabin, L_{pA}, due to these shall be determined when the external noise sources in the room have been switched off.

For cabins with one or more well-defined operators' positions, the sound pressure level shall be measured at these positions according to the method specified in 6.5.2.

For cabins with no well-defined operators' positions, the sound pressure level shall be measured close to the middle of the cabin at three microphone positions on a sphere with radius 0,3 m or by averaging over a circular microphone path with a radius of 0,3 m. The path shall be inclined by 45° relative to the horizontal plane. The centre of the measurement sphere/circle shall be 1,55 m ± 0,075 m above floor level. The measurement result, L_{pA}, is the average value determined on a mean-square basis.

The background noise level inside the cabin (when integrated noise sources are switched off) shall be at least 6 dB and preferably more than 12 dB below the sound pressure level from the noise sources to be measured. If the difference is in the range 6 dB to 10 dB, the result of the measurement shall be corrected for the effect of the background noise in accordance with ISO 3741.

7 Measurement of sound insulation performance *in situ*

7.1 General

Two methods are specified, one where the sound field is generated by loudspeakers and one where the actual environmental noise is used. The loudspeaker method is preferred if the purpose of the *in situ* measurement is to achieve results comparable with laboratory results. The actual noise method is used to estimate the sound insulation performance of the cabin under actual conditions.

A sound field is generated in the room and the sound pressure level difference between the room and the inside of the cabin is measured.

These methods are applicable for *in situ* measurements in all types of rooms.

7.2 External sound field

If several possibilities exist for choosing a room for the measurement, select the room in which the best approximation of a reverberant sound field is expected. This normally means the room with the largest volume and the longest reverberation time.

7.2.1 Measurement with a loudspeaker

This method is preferred if the purpose of the measurement is to compare the sound insulation performance *in situ* with results of laboratory measurements.

The sound field shall be generated by a loudspeaker source using at least three different positions. The number of source positions shall be equal to or greater than the maximum deviation, in decibels, of D'_p between any two source positions using octave bands. The number of source positions shall be increased to a maximum of six. If the deviation, in decibels, in any octave band exceeds the maximum number of source positions (six), this shall be stated in the report.

If the requirement stated above cannot be fulfilled with three loudspeaker positions, then try with four positions. The three positions used first should not be used again for the measurement with four positions. If a further increase in number of positions is necessary, the same procedure should be used.

The distance between the loudspeaker positions shall be at least 3 m. The loudspeaker positions shall be uniformly distributed around the cabin. Either one loudspeaker cabinet can be moved between the chosen positions with the measurements carried out sequentially, or several loudspeakers can be operating simultaneously provided that they are incoherent (having a separate noise generator and power amplifier for each loudspeaker).

The average sound pressure level over different loudspeaker positions in the room shall be determined on a mean-square basis.

Care shall be taken to avoid any influence of the direct sound field from the sound source. The distance between the cabin and the sound source shall not be less than 2 m.

NOTE 12 The minimum distance of 2 m will be sufficient provided that the loudspeaker is approximately omnidirectional and that loudspeaker positions close to room surfaces or corners are avoided.

The generated sound shall be steady and have a continuous spectrum over the frequency range