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Acoustics — Test methods for the qualification of free-field environments

Acoustique — Méthodes d'essai pour la qualification des environnements en champ libre

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 43, *Acoustics*.

This second edition cancels and replaces the first edition (ISO 26101:2012), which has been technically revised. The main changes are as follows:

— the term "acoustic centre" was replaced by "mathematical origin of the traverse" in several places in the document to provide clarification of terminology;

— the minimum traverse path length was reduced from 1/2 wavelength to 1/4 wavelength;

— Figure B.1 has been added.

Introduction

This document describes the divergence loss method of measurement of performance of an environment designed to provide a free sound field or free sound field over a reflecting plane. An acoustical environment is a free sound field if it has bounding surfaces that absorb all sound energies incident upon them. This is normally achieved using specialized test environments, such as anechoic or hemi-anechoic chambers. In practice, these provide a controlled free sound field for acoustical measurements in a confined space within the facility.

The purpose of this document is to promote uniformity in the method and conditions of measurement when qualifying free sound field environments.

It is expected that the qualification procedures outlined in this document will be referred to by other International Standards and industry test codes. In such cases, these documents making reference to this document may specify qualification criteria appropriate for the test method and may require specific traverse paths.

Acoustics — Test methods for the qualification of free-field environments

1 Scope

This document specifies methodology for qualifying acoustic spaces as anechoic and hemi-anechoic spaces meeting the requirements of a free sound field.

This document specifies discrete-frequency and broad-band test methods for quantifying the performance of anechoic and hemi-anechoic spaces, defines the qualification procedure for an omni-directional sound source suitable for free-field qualification, gives details of how to present the results and describes uncertainties of measurement.

This document has been developed for qualifying anechoic and hemi-anechoic spaces for a variety of acoustical measurement purposes. It is expected that, over time, various standards and test codes will refer to this document in order to qualify an anechoic or hemi-anechoic space for a particular measurement.

In the absence of specific requirements or criteria, Annex A provides qualification criteria and measurement requirements to qualify anechoic and hemi-anechoic spaces for general purpose acoustical measurements.

This document describes the divergence loss method for measuring the free sound field performance of an acoustic environment.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

IEC 61260-1, *Electroacoustics — Octave-band and fractional-octave-band filters — Part 1: Specifications*

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
free sound field
sound field in a homogeneous, isotropic medium free of boundaries

[SOURCE: ISO/TR 25417:2007, 2.17]

3.2
anechoic space
volume which has been qualified as a sound field in a homogeneous, isotropic medium free of boundaries

3.3
hemi-anechoic space
volume above a reflecting plane which has been qualified as a sound field in a homogeneous, isotropic medium free of boundaries

3.4
acoustic centre
<for a sound source and for a given test signal> position of the point from which approximately spherical wave fronts appear to diverge

3.5
background noise
sum of all the signals except the one under investigation

Note 1 to entry: Background noise can include contributions from airborne sound, structure-borne vibration and electrical noise in instrumentation.

3.6
divergence loss
reduction in sound pressure along a straight path due to the spreading of sound when a sound wave propagates away from a source

3.7
frequency range of interest
contiguous one-third-octave-band frequencies from the lowest to the highest frequencies to be qualified, inclusive

3.8
referencing document
standard or test code that refers to this document for the purpose of specifying the qualification method of an *anechoic* (3.2) or *hemi-anechoic space* (3.3)

4 Allowable deviations from inverse square law

The theoretical reduction in mean-square sound pressure along a straight path due to spherical propagation of a sound wave in a free sound field shall be hereafter referred to as the inverse square law.

For a space to be deemed anechoic or hemi-anechoic, as defined by criteria in a referencing document, the deviations of the measured sound pressure levels from those estimated using the inverse square law, obtained according to this document, shall not exceed the values specified by the referencing document.

In the absence of specific criteria for the allowable deviations in a referencing document, the criteria in Annex A shall be used to qualify anechoic and hemi-anechoic spaces for general purpose acoustical measurements.

The allowable deviations specified by a referencing document may be more or less stringent than the criteria given in Annex A.

5 Measurement of free sound field performance

5.1 Divergence loss method

5.1.1 Principle

The divergence loss method shall be used to quantify the performance of an anechoic or hemi-anechoic space within a test environment and to determine the spatial limits of this qualified anechoic or hemi-anechoic space.

The free sound field performance is evaluated by quantifying the contributions of both the direct and the reflected components of acoustic energy.

The spatial decrease of sound pressure emitted from a test sound source shall be compared with the decrease of sound pressure that would occur in an ideal free sound field.

5.1.2 Instrumentation and measuring equipment

5.1.2.1 General

The instrumentation system for measuring sound pressure level, including the microphone and cable, shall be operated within the limit of the linearity errors specified for a Class 1 sound level meter according to IEC 61672-1.

The microphone shall be nominally omni-directional (taking into account any supplementary equipment connected to it, such as the protective grid and mounting arrangement).

For measurements in one-third-octave bands, the filters used shall meet the requirements for Class 1 specified in IEC 61260-1.

NOTE For measurements above 5 kHz, this method will normally require a microphone of diameter equivalent to that of a WS2F microphone, as described in IEC 61094-4[2], or less.

5.1.2.2 Test sound source

A sound source approximating a point source over the frequency range of interest shall be used for the qualification measurement. The source shall be

a) compact and of acoustical performance, such that the location of the acoustic centre of the source is known to be located close enough to the origin of the microphone traverses specified in 5.1.3.2 to allow fitting of the sound pressure level versus distance data without an adjustment for the acoustic centre of the source,

b) in compliance with the directionality criteria in Table B.1, when measured according to the procedure in Annex B, so as to ensure the source radiates energy in all directions,

c) able to generate sufficient sound power over the frequency range of interest to yield sound pressure levels at least 6 dB above the background noise levels for all points on each microphone traverse, or while the microphone is moving for continuous traverse systems,[3] and

d) of high stability so that the radiated sound power (due to the source, associated signal generation and amplification electronics) as measured by a monitor microphone located at an arbitrary fixed position in the test environment does not vary significantly at the frequency of measurement during the time taken to complete the measurements for each microphone traverse. If the stability of the source varies by more than ±0,2 dB then the monitor microphone shall be used to apply a correction according to Formula (1):

$$L_{pi} = L'_{pi} - L_{p,\text{ref},i} + L_{p,\text{ref},0} \tag{1}$$

where

L_{pi} is the corrected sound pressure level at measurement point *i*, expressed in decibels (dB);

L'_{pi} is the measured sound pressure level at measurement point *i*, expressed in decibels (dB);

$L_{p,\text{ref},i}$ is the sound pressure level measured by the monitor microphone at the reference location for measurement point *i*, expressed in decibels (dB);

$L_{p,\text{ref},0}$ is the sound pressure level measured by the monitor microphone at the reference location for the initial measurement point 0, expressed in decibels (dB).

Since, in general, two or more sources may be required to cover the overall frequency range of interest, the requirements given above shall be met for each source over its applicable frequency range.

NOTE It is possible to estimate the acoustic centre of a source by evaluating it in an anechoic space already known to meet the requirements in Annex A.

Care should be taken

— to ensure that the sound pressure levels are more than 6 dB, and preferably more than 15 dB, above the background noise levels;

— in positioning the monitor microphone to avoid acoustic interference with the traversing mechanism affecting the results;

— to ensure that changes in atmospheric conditions over the duration of the traverse are not confused with those related to the source stability.

5.1.3 Location of test sound sources and microphone traverses

5.1.3.1 Test sound source location

Referencing documents may specify the test sound source location(s) to be used in order to qualify the anechoic or hemi-anechoic space.

In the absence of specific requirements for the sound source location in a referencing document, the requirements in Annex A shall be used to qualify anechoic and hemi-anechoic spaces for general purpose acoustical measurements.

The test sound source should be placed in a chosen orientation and held in that orientation for all microphone traverses.

An environment may be qualified for more than one source location.

5.1.3.2 Microphone traverses

Microphone traverses shall be made along paths that will characterize and qualify the anechoic or hemi-anechoic space for the types of acoustical measurements to be conducted in the test environment. The origin of the microphone traverse shall be within the physical volume occupied by the test sound source.

Referencing documents may specify the traverse paths to be conducted in order to qualify the anechoic or hemi-anechoic space.

In the absence of specific requirements for the traverse paths in a referencing document, the requirements in Annex A shall be used to qualify anechoic and hemi-anechoic spaces for general purpose acoustical measurements.

Sound reflection from the microphone support system should be carefully avoided.

5.1.4 Test procedure

5.1.4.1 Qualification bandwidth

The qualification measurements of the anechoic or hemi-anechoic space shall be made using a bandwidth that is typical of the spectral characteristics of the type of sources that will be measured or evaluated.

Discrete-frequency qualification may be accomplished by using a test source that generates discrete tone(s) or by using a test source that generates broad-band noise and a measurement system that provides discrete-frequency measurement capabilities, such as an FFT analyser[3].

Broad-band qualification may be accomplished by using a test source that generates broad-band noise and a measurement system that provides one-third-octave-band filtering.

Referencing documents may specify the bandwidth for the qualification measurement.

In the absence of specific requirements for the bandwidth in a referencing document, the requirements in Annex A shall be used for the selection of the appropriate qualification measurement bandwidth for their intended purpose.

5.1.4.2 Generation of sound

The test sound source described in 5.1.2.2 may be operated with a test signal of pure tones, multiple pure tones, band-limited or broad-band noise.

If pure tones or multiple pure tones are used for discrete-frequency qualification, the measured signal after any filtering shall not contain energy at frequencies not being characterized that are within 15 dB of the frequencies being characterized. If broad-band noise is used as a test signal for either broad-band or discrete-frequency qualification, then the test signal shall consist of either random noise or broad-band test signals derived from random noise.

In the absence of specific requirements for the test signal in a referencing document, the requirements in Annex A shall be used for the selection of the appropriate test signal for qualification of anechoic or hemi-anechoic spaces for their intended purpose.

NOTE Use of a mix of pure tones spaced apart by more than a one-third-octave band can be much more rapid than sequential traverses, each at a single pure tone.

When using tonal or mixed tone signals, care should be taken to avoid distortion due to excessive signal levels.

5.1.4.3 Measurement of sound pressure level

The sound pressure levels shall be measured using fractional octave-band filters or FFT analysis.

The microphone shall be moved along the paths described in 5.1.3.2 for each test signal. The measurement of sound pressure level shall be carried out starting, at most, a quarter of a wavelength (at the lowest frequency to be qualified) from the origin of the traverse, traversing at least a quarter of a wavelength (at the lowest frequency to be qualified) and to the hypothetical boundary of the anechoic or hemi-anechoic space to be qualified.

Sound pressure levels shall be measured along each microphone traverse using equally spaced measurement points at each frequency. Referencing documents may specify the maximum spacing of the measurement points in order to qualify the anechoic or hemi-anechoic space for their intended purpose.

In the absence of specific requirements for the spatial resolution of the measurement points, the requirements in Annex A shall be used to qualify anechoic and hemi-anechoic spaces for general purpose acoustical measurements.

Alternatively, for discrete-frequency measurements using pure tone signals, the microphone may be moved slowly and continuously along the traverse and the sound pressure levels recorded[3]. Sound pressure level versus distance data should then be determined using the spatial sampling guidelines for discrete measurements.

If broad-band test signals are used, measurement times should be of sufficient duration to achieve stable levels.

5.1.5 Expression of results

5.1.5.1 Method of calculation

5.1.5.1.1 General

Measured sound pressure levels are compared with the theoretical sound pressure level decay according to the inverse square law in a free sound field.

5.1.5.1.2 Formula for estimation of sound pressure levels based on the inverse square law

From the sound pressure levels measured at positions specified in 5.1.4.3, the estimation of sound pressure levels based on the inverse square law shall be determined for each measurement traverse using Formula (2):

$$L_p(r_i) = b - 20\lg\left(\frac{r_i}{r_0}\right)\text{dB} \tag{2}$$

where

- $L_p(r_i)$ is the sound pressure level at distance r_i estimated by the inverse square law, expressed in decibels (dB);
- r_i is the distance of measurement point i from the mathematical origin of the traverse, expressed in metres (m);
- r_0 is the reference value, r_0 = 1 m;
- b is the source strength parameter that is adjusted to optimize the fit of the measured sound pressure levels into the tolerance range, to maximize the qualified distance from the test sound source, expressed in decibels (dB).

If a continuous traverse is used, an “analogue” recording of level versus distance is obtained. To use the formulae in this clause, sound pressure levels at a large number of points at regularly spaced intervals shall be derived from the records. The selection of point spacing shall be based on the criteria of 5.1.4.3.