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Acoustics — Sound-scattering properties of surfaces —

Part 2:
Measurement of the directional diffusion coefficient in a free field

Acoustique — Propriétés de dispersion du son par les surfaces —
Partie 2: Mesurage du coefficient de diffusion directionnel en champ libre

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 17497-2 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*.

ISO 17497 consists of the following parts, under the general title *Acoustics — Sound-scattering properties of surfaces*:

- *Part 1: Measurement of the random-incidence scattering coefficient in a reverberation room*
- *Part 2: Measurement of the directional diffusion coefficient in a free field*

Introduction

The degree of acoustic scattering from surfaces is very important in all aspects of room acoustics, e.g. in concert halls, sound studios, industrial halls and reverberation chambers. The degree of scattering and absorption in a room are important factors related to the acoustic quality of the room. This part of ISO 17497 addresses the measurement and characterization of scattering surfaces.

The scattering coefficient is introduced in ISO 17487-1. In this part of ISO 17487, a measurement method for the directional diffusion coefficient is introduced. The diffusion coefficient is different from, but related to, the random incidence scattering coefficient. While the scattering coefficient is a rough measure that describes the degree of scattered sound, the diffusion coefficient describes the directional uniformity of the scattering, i.e. the quality of the diffusing surface. Consequently, there is a need for both concepts, and they have different applications.

The work has been coordinated with the working group of the Audio Engineering Society, AES SC-04-02 for the Characterization of Acoustical Materials.

Acoustics — Sound-scattering properties of surfaces —

Part 2:
Measurement of the directional diffusion coefficient in a free field

1 Scope

This part of ISO 17497 specifies a method of measuring the directional diffusion coefficient of surfaces.

The diffusion coefficient characterizes the sound reflected from a surface in terms of the uniformity of the reflected polar distribution. The diffusion coefficient is a measure of quality designed to inform producers and users of surfaces that, either deliberately or accidentally, diffuse sound. It can also inform developers and users of geometric room acoustic models. The diffusion coefficient is not suitable for direct use as an input to current diffusion algorithms in geometric room acoustic models.

This part of ISO 17497 details a free-field characterization method.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 266, *Acoustics — Preferred frequencies*

IEC 61260, *Electroacoustics — Octave-band and fractional-octave-band filters*

3 Terms and definitions

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

3.1
sound ray
line following one possible direction of sound propagation from a source point

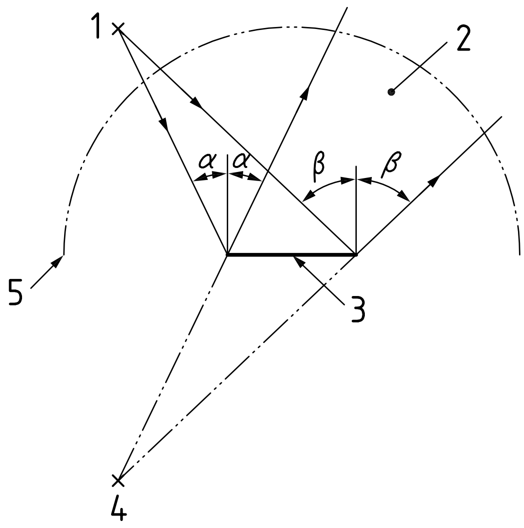
3.2
specular reflection
reflection that obeys Snell's law, i.e. the angle of reflection is equal to the angle of incidence

Note 1 to entry Specular reflection can be obtained approximately from a plane, rigid surface with dimensions much larger than the wavelength of the incident sound.

3.3
specular zone
area contained by imaginary lines that are constructed from the image source, which is created about the plane of a specified reference flat surface via the edges of that surface to the receiver arc or hemisphere

Note 1 to entry The reference flat surface is a plane and rigid surface, with the same projected shape or footprint as the test surface.

Note 2 to entry The position at which an imaginary line from the image source to a receiver crosses the diffuser is the specular reflection point (see Figure 1).



Key

1 source

2 specular zone

3 diffuser

4 image source

5 receiver arc

Figure 1 — Representation of specular zone

3.4
far field
region in which the reflected sound pressure level from the test surface decays by 6 dB per doubling of distance

Note 1 to entry In the near field, the shape of the angular field distribution is dependent on the distance from the diffuser.

3.5
single plane diffuser
surface that displays distinct anisotropic behaviour, as can be the case for a cylinder or a one-dimensional Schroeder diffuser

Note 1 to entry For these surfaces, the diffusion is measured in the plane of maximum diffusion.

3.6
multiple-plane diffuser
surface that is expected to display more approximately isotropic behaviour, as can be the case for a hemisphere or a two-dimensional Schroeder diffuser

Note 1 to entry For these surfaces, hemispherical evaluation is appropriate, yielding a single diffusion coefficient. Alternatively, measurements can be done in two orthogonal planes.

3.7
semicircular polar response
sound pressure level created by energy scattered from the surface as a function of angle measured about the reference normal, generated under free-field or pseudo-free-field conditions, in a specified plane, on a semicircle centred at the reference point, at an appropriate radial distance

Note 1 to entry The reference normal is an outward-pointing vector perpendicular to the front face of a reference flat surface. The reference point is the geometric centre of gravity of the reference flat surface

3.8
hemispherical polar response

sound pressure level scattered from the surface as a function of spherical coordinates measured about the reference normal, generated under free-field or pseudo-free-field conditions, on a hemisphere centred at the reference point

3.9
directional diffusion coefficient

$d_{\theta,\phi}$

measure of the uniformity of diffusion produced by a surface for one source position

Note 1 to entry The value of $d_{\theta,\varphi}$ is bounded between 0 and 1. When complete diffusion is achieved by the surface, the diffusion coefficient is 1. However, real diffusers rarely have diffusion coefficients higher than 0,7. If only one receiver receives non-zero scattered sound pressure, the diffusion coefficient is 0. The subscript θ is used to indicate the angle of incidence relative to the reference normal of the surface. The ϕ indicates the azimuth angle.

3.10
random incidence diffusion coefficient

d

measure of the uniformity of diffusion for a representative sample of sources over a complete semicircle for a single plane diffuser, or a complete hemisphere for a hemispherical diffuser

Note 1 to entry A mean or a weighting of the directional diffusion coefficients for the difference source positions is used to calculate the diffusion coefficient, as specified in 8.4. A guideline to achieve a representative sample of sources is given in 6.2.2. The lack of a subscript for d indicates random incidence.

3.11
normalized directional diffusion coefficient

$d_{\theta,\phi,\mathrm{n}}$

directional diffusion coefficient of the test specimen normalized to that of the reference flat surface

3.12
normalized diffusion coefficient

d_n

random incidence diffusion coefficient determined from the normalized directional diffusion coefficient

3.13
physical scale ratio

1:N

ratio of any linear dimension in a physical scale model to the same linear dimension in full scale

Note 1 to entry The wavelength of the sound used in a scale model for acoustic measurements obeys the same physical scale ratio. Therefore, if the speed of sound is the same in the model as in full scale, the frequencies used for the model measurements are a factor of N times higher than in full scale.

4 Measurement principle

The diffusion coefficient quantifies how the energy reflected from a surface is spatially distributed. This spatial distribution is described by polar responses of the reflected sound pressure level. A source is used to irradiate the test surface, and microphones at radial positions in front of the surface are used to measure the sound. The reflected sound is extracted from the microphone signals using the process outlined in Clause 7. The diffusion coefficient is then calculated from the reflected sound pressure levels using the equations shown in Clause 8. To remove finite-panel effects, which cause the diffusion coefficient to decrease as the frequency increases, a normalized diffusion coefficient is calculated.

The microphone positions should map out a semicircle or hemisphere, for a single plane or hemispherical measurement, respectively. Single-plane diffusers can be measured using a two-dimensional goniometer, either using a boundary plane measurement (see Figure 3) or in an anechoic chamber. A multi-plane diffuser can be characterized by making two single plane measurements in orthogonal planes in a two-dimensional goniometer — this is the quickest and easiest approach. Alternatively, a hemispherical measurement can be done using a three-dimensional goniometer (see Figure 2).

5 Frequency range

The measurements shall be performed in one-third-octave bands with centre frequencies covering the frequency range from 100 Hz to 5 000 Hz, in accordance with IEC 61260 and ISO 266. This refers to full-scale measurements. If a physical scale factor of 1:N is used, the centre frequencies should cover the frequency range from $N \times$ 100 Hz to $N \times$ 5 000 Hz.

If the scale model is filled with a gas in which the speed of sound is different from that in atmospheric air, the measurement frequencies shall be chosen in such a way that the wavelength obeys the physical scale ratio 1:N.

High frequencies may be omitted from the measurements if the attenuation in the air is too high.

6 Test arrangement

6.1 Measurement environment

Annex A describes the measurement environments that shall be used. A qualified anechoic chamber can be used. An implementation of such a set-up is illustrated in Figure 2. Alternatively, a large non-anechoic space can be used to simulate a reflection-free environment if certain techniques described in Annex A are used.

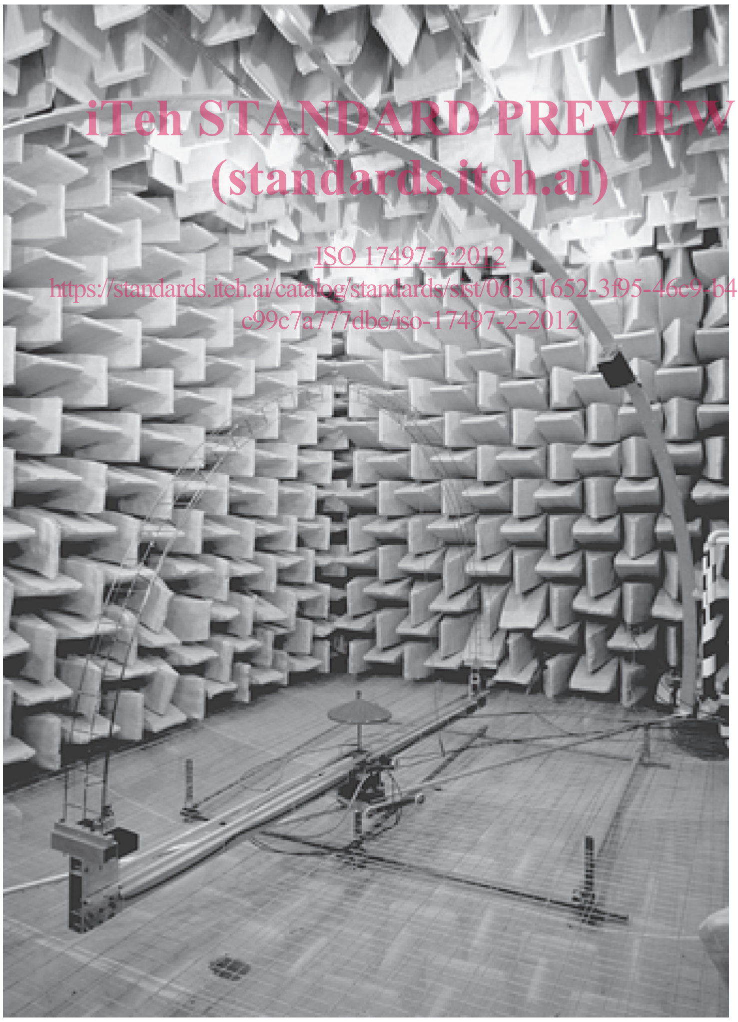


Figure 2 — Three-dimensional measurement goniometer

Boundary measurements may also be carried out to remove the necessity for a space to be anechoic in one plane provided conditions in Annex A are satisfied. An implementation of such a set-up is illustrated in Figure 3.

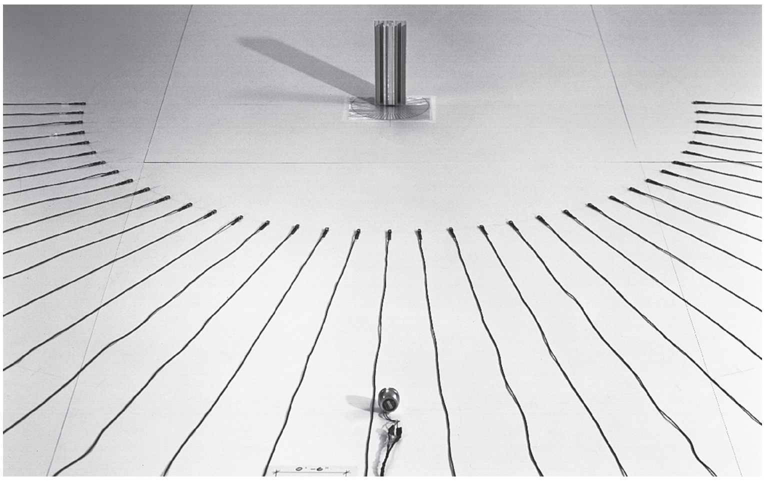


Figure 3 — Two-dimensional boundary measurement technique

Scale models may be used to evaluate the diffusion from test surfaces. If the speed of sound is the same in the model as in full scale, then the frequencies used for the model measurements shall be a factor of N higher than in full scale. For scale models, the absorption properties shall be the same for both the full-scale surface at full-scale frequencies and the test surface sample at the equivalent model-scale frequency. When considering absorption from samples, losses due to viscous boundary layer effects shall be included. This inclusion can limit the useable model scales.

6.2 Measurement field

6.2.1 Near-field versus far-field measurements

Diffusers may be applied in situations where some or all sources and receivers are in the near field. In such cases, measurements to determine the diffusion coefficient should take place both at application-realistic near-field positions and in the far field. The tests in the far field monitor the amount of diffusion achieved, measurements in the near field shall be used to check for near-field aberrations, particularly focusing.

An exception to the preceding rule occurs if the diffuser is to be applied only for far field sources and receivers, in which case, diffusion coefficient measurements may be undertaken only in the far field.

When comparing test surfaces, the same geometry shall be used in each case to avoid errors. Full geometry information, source locations, receiver positions, and test surface dimensions and construction shall be quoted in reports.

6.2.2 Far-field measurements

Approximate far-field conditions can be achieved if at least 80 % of the receiver positions are outside the specular zone, see Figure 4. The source to reference-point distance should be 10 m and the receiver's semi-circle or hemisphere should have a radius of 5 m.

Measurements shall be made with a maximum receiver angular resolution of 5° (i.e. $\Delta\theta \leq 5°$ and $\Delta\phi \leq 5°$). This may be achieved using either a discrete fixed position system or a continuous moving system.

To obtain a random-incidence diffusion coefficient of a hemispherical diffuser, source positions covering a hemisphere shall be selected with the azimuth and elevation angles as given in Table 1. For the definition of angles, see Figure 7. For a survey measurement, the four positions with numbers 1, 8, 10, and 12 in Table 1 should be used.

When the two-dimensional boundary measurement technique is used, the preferred source positions are at the angles 0°, ±30°, and ±60° relative to the reference normal.