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Acoustics — Determination of airflow resistance —

Part 2: Alternating airflow method

Acoustique — Détermination de la résistance à l'écoulement de l'air —

Partie 2: Méthode avec écoulement d'air alternatif

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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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, 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 www.iso.org/iso/foreword.html.

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

This first edition of ISO 9053-2, together with ISO 9053-1:2018, cancels and replaces ISO 9053:1991, which has been technically revised.

The main changes compared to the previous edition are as follows:

— the former method B in ISO 9053:1991 has been transferred to this document;

— the requirement to the dimensions of the test specimen have been updated;

— a correction for heat conduction has been added.

A list of all parts in the ISO 9053 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Acoustics — Determination of airflow resistance —

Part 2:
Alternating airflow method

1 Scope

This document specifies an alternating airflow method for the determination of the airflow resistance[5], [6] of porous materials for acoustical applications.

Determination of the airflow resistance based on static flow is described in ISO 9053-1.

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)*

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:

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

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

3.1
airflow resistance
R
quantity defined by

$$R = \frac{\Delta p}{q_\mathrm{v}}$$

where

Δp is the RMS air pressure difference, across the test specimen, due to the alternating airflow, in pascals;

q_v is the RMS volumetric airflow rate, passing through the test specimen, in cubic metres per second.

Note 1 to entry: Airflow resistance is expressed in pascals seconds per cubic metre.

3.2
specific airflow resistance

R_s

quantity defined by

$$R_s = R \cdot A$$

where

R is the airflow resistance of the test specimen, in pascals seconds per cubic metre;

A is the cross-section area of the test specimen, perpendicular to the direction of flow, in square metres.

Note 1 to entry: Specific airflow resistance is expressed in pascals seconds per metre.

3.3
airflow resistivity

σ

quantity defined by the following formula if the material is considered as being homogeneous

$$\sigma = \frac{R_s}{d}$$

where

R_s is the specific airflow resistance of the test specimen, in pascals seconds per metre;

d is the thickness of the test specimen, in the direction of flow, in metres.

Note 1 to entry: Airflow resistivity is expressed in pascals seconds per square metre.

3.4
airflow velocity

v

quantity defined by

$$v = \frac{q_v}{A}$$

where

q_v is the RMS volumetric airflow rate, passing through the test specimen, in cubic metres per second;

A is the cross-sectional area of the test specimen, perpendicular to the direction of flow, in square metres.

Note 1 to entry: Airflow velocity is expressed in metres per second.

3.5

sound pressure level

L_p

ten times the logarithm to the base 10 of the ratio of the time average of the square of the sound pressure, $p(t)$, during a stated time interval of duration, T (starting at t_1 and ending at t_2), to the square of a reference value, p_0:

$$L_p = 10 \lg \left(\frac{\frac{1}{T} \int_{t_1}^{t_2} p^2(t) \mathrm{d}t}{p_0^2} \right) \mathrm{dB}$$

where the reference value, p_0, is 20 µPa

Note 1 to entry: The sound pressure level is expressed in decibels.

4 Symbols

A	cross-section area of the test specimen, in square metres;
A_P	cross sectional area of the piston, in square metres;
b	thickness of the thermal boundary layer, in metres;
C_P	specific heat capacity at constant pressure, in joules per kilogram and degree kelvin;
c_0	speed of sound, in metres per second;
d	thickness of the test specimen, in the direction of flow, in metres;
f	frequency of the piston movement, in hertz;
h	amplitude of the stroke of the piston, in metres;
h_s	amplitude of the stroke of the piston when the measurement cell with the test specimen is mounted, in metres;
h_t	amplitude of the stroke of the piston when the air cavity is closed by the airtight termination, in metres;
j	$\sqrt{-1}$
k_a	thermal conductivity, in joules per meter, second and degree kelvin;
L_p	sound pressure level, in decibels;
$L_{p,b}$	background sound pressure level, in decibels;
$L_{p,s}$	sound pressure level in the air cavity when the measurement cell with the test specimen is mounted, in decibels;
$L_{p,t}$	sound pressure level in the air cavity with the airtight termination, in decibels;
l_h	characteristic thermal diffusion length, in metres;
N	acoustic compliance, in cubic metres per pascal;
P_S	static pressure, in pascals;

p	sound pressure, in pascals;
p_s	sound pressure when the test cell with the test specimen is mounted, in pascals;
p_t	sound pressure when the air cavity is closed by the airtight termination, in pascals;
p_0	sound pressure reference value, 20 µPa;
q_s	rms value of the volume flow when the test cell with the test specimen is mounted, in cubic metres per second;
q_t	rms value of the volume flow when the air cavity is closed by the airtight termination, in cubic metres per second;
q_v	rms volumetric airflow rate, passing through the test specimen, in cubic metres per second;
R	airflow resistance of the test specimen, in pascals seconds per cubic metre;
R_s	specific airflow resistance of the test specimen, in pascals seconds per metre;
r	ratio between the stroke amplitudes;
r_r	radius of the perforations in the specimen support (Annex D), in metres;
S	total area, in square metres;
U	expanded uncertainty;
u	standard uncertainty;
V	volume of the air cavity with the airtight termination, in cubic metres;
v	airflow velocity, in metres per second;
v_s	rms-value of the airflow velocity through the test specimen, in metres per second;
y	thickness of the support, in metres;
Z_a	acoustic impedance of the cavity, in pascals seconds per cubic metres;
Δp	rms air pressure difference, across the test specimen, due to the alternating airflow, in pascals;
ϕ	perforation rate;
η	dynamic viscosity of air, in pascals seconds;
κ	ratio of specific heats for air;
κ'	effective ratio of specific heats for air;
λ	wavelength, in metres;
ρ_0	density of air, in kilograms per cubic metre;
σ	airflow resistivity of the test specimen, in pascals seconds per square metre;
ω	circular frequency, $2 \cdot \pi \cdot f$, in per second.

5 Principle

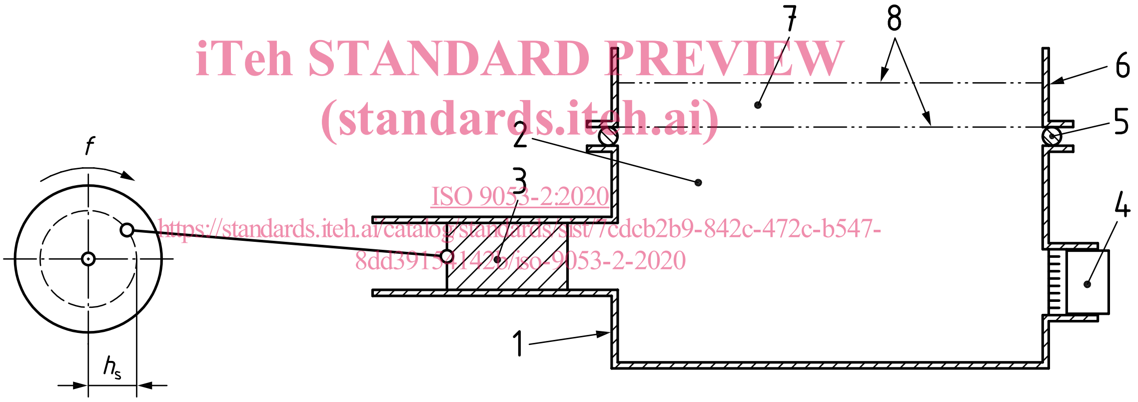
An alternating volume flow with a low frequency, f , for example of 2 Hz, is generated by a piston or similar device (see Figure 1 and Figure 2) moving sinusoidally. This volume flow acts on an air cavity that is either closed by an airtight termination or terminated by the test specimen mounted in a measurement cell. The sound pressure level is measured in the air cavity for both cases.

The pressure inside the cavity is the outside atmospheric pressure modulated by the alternating flow generated by the piston. The microphone mounted inside the cavity therefore measures the pressure difference across the specimen when the test cell with the specimen is mounted.

When the air cavity is closed, the volume flow creates a sound pressure in the air cavity that can be calculated from the piston movement, the dimensional information of the cavity and the atmospheric air pressure.

When the measurement cell is mounted, the main part of the generated volume flow passes through the test specimen and a lower sound pressure is observed in the air cavity. The difference between the sound pressure levels when the vessel is closed and when the test cell is mounted is a direct function of the airflow resistivity of the test specimen. By the measurement of the sound pressure differences, the airflow resistance for the test specimen can be computed.

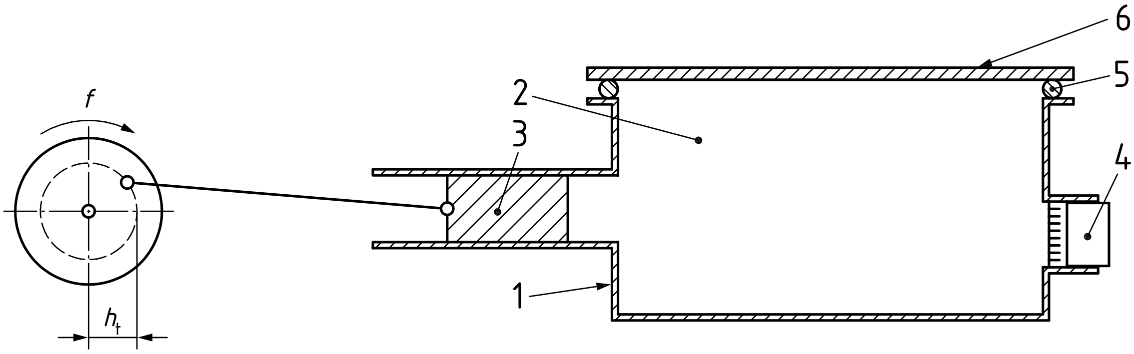
It can be practical to use different piston stroke lengths for the closed vessel and when the measurement cell is mounted.



Key

1	vessel	2	air cavity
3	piston	4	microphone
5	seal	6	measurement cell
7	test specimen	8	optional support for test specimen

Figure 1 — Basic principle, termination with the test specimen



Key

1	vessel	2	air cavity
3	piston	4	microphone
5	seal	6	airtight termination

Figure 2 — Basic principle, termination with an airtight seal

NOTE For materials with a visco-inertial transition frequency below 100 Hz, the method described in ISO 9053-1 using a static flow can give a different result. Examples of such materials are: a) fibre materials with large fibres, such as some metal or plant fibres, b) foams with low porosity but big pores, such as some metal foams, c) granular materials with large grains and low porosity, such as road pavements.

6 Equipment

6.1 General

The equipment shall consist of:

a) a device for producing the alternating airflow (see 6.2);

b) a sound level meter or an alternative device for measuring the sound pressure level in a narrow frequency band (e.g. a fractional-octave band) around the frequency of the piston (see 6.3);

c) a vessel (see 6.4)

- containing the air cavity,
- allowing connections to the microphone and the source of the alternating airflow, and
- including an airtight termination and a measurement cell;

d) a device for measuring the static pressure (see 6.5);

e) a device for measuring the frequency of the piston (see 6.6);

f) a device for measuring the thickness of the test specimen when it is positioned for the test.

6.2 Device for producing the alternating airflow

The alternating airflow shall be produced by a sinusoidally moving piston. The frequency of the piston movement, f, shall be in the range of 1 Hz to 4 Hz and known with sufficient accuracy (see Annex C).

The amplitude of the piston stroke, h (see Figure 1 and Figure 2), shall be determined, normally by dimensional measurements. The rms-value of the volume flow, q_v, produced by the moving piston is

$$q_\mathrm{v} = \sqrt{2} \cdot \pi \cdot f \cdot h \cdot A_\mathrm{P}$$

Different stroke lengths can be applied for the measurement with the airtight termination and the measurement cell with specimen. The two lengths shall be selected to obtain suitable sound pressure levels in both situations as well as to generate the required airflow velocity through the specimen. The use of different piston frequencies and stroke lengths can be used to demonstrate that the obtained airflow resistance is independent of the airflow velocity.

The rms-value of the flow velocity through the test specimen, in metres per second, is calculated according to Formula (1):

$$v_\mathrm{s} = \frac{\sqrt{2} \cdot \pi \cdot f \cdot h_\mathrm{s} \cdot A_\mathrm{P}}{A} \tag{1}$$

It is recommended to use rms-values of the flow velocity between $5 \cdot 10^{-4}\ \mathrm{m\,s^{-1}}$ and $4 \cdot 10^{-3}\ \mathrm{m\,s^{-1}}$.

NOTE 1 A piston with a diameter of 10 mm and stroke lengths of 1,4 mm (airtight termination) and 14 mm (measurement cell with specimen) has proven to be appropriate for a measurement cell diameter of 100 mm and an air cavity with a volume of about $10^{-3}\ \mathrm{m}^3$.

NOTE 2 The uncertainty analysis shows that the ratio between the different applied stroke lengths is important. The ratio can be verified by using a sound level measuring system that covers the pressures generated by all the applied strokes lengths.

6.3 Sound measuring device

The sound measuring device shall be able to measure sound pressures with the piston frequency. The applied sound pressure shall be within the linear measurement range for the device.

The sound measuring device shall have a small bandwidth around the piston frequency for reducing background noise and harmonic distortions.

For all related measurements at a particular piston frequency including measurement of background noise, the bandwidth of the sound measuring device shall not be changed.

The sound measuring device may be a sound level meter, including microphones and cables, conforming to the requirements of IEC 61672-1 class 1 or class 2, and with fractional-octave band filters meeting the requirements of IEC 61260-1 class 1 or class 2.

It is important that the sound measuring device only measure the sound with frequencies close to the frequency of the piston in order to reduce the effect of harmonic distortions and background noise. The band limiting function can be obtained by the use of a fractional-octave band filter or FFT-analyser/technique.

NOTE The sound measuring device is mainly used to determine the difference in sound pressure levels for sound with a constant frequency. Level linearity performance at this frequency is therefore the most important property.

6.4 Vessel and measurement cell

The vessel and the measurement cell shall be in the shape of a circular cylinder or a rectangular parallelepiped (preferably with a square cross-section in the latter case). The vessel shall include appropriate seals to enable a leak-free mounting of the airtight termination and the measurement cell. The vessel and the airtight termination shall be sufficiently stiff to avoid volume changes under alternating pressure conditions. The volume, V, of the air cavity inside the closed vessel with the