# SLOVENSKI STANDARD
# oSIST prEN ISO 10534-2:2022

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**Akustika - Ugotavljanje akustičnih lastnosti v Kundtovi cevi - 2. del: Dvomikrofonska tehnika za določanje normalnega koeficienta absorpcije zvoka in normalne površinske impedance (ISO/DIS 10534-2:2022)**

Acoustics - Determination of acoustic properties in impedance tubes - Part 2: Two-microphone technique for normal sound absorption coefficient and normal surface impedance (ISO/DIS 10534-2:2022)



Akustik - Bestimmung der akustischen Eigenschaften in Impedanzrohren - Teil 2: 2-Mikrofontechnik für Standardschallabsorptionsgrad und Standardoberflächenimpedanz (ISO/DIS 10534-2:2022)



Acoustique - Détermination des propriétés acoustiques aux tubes d'impédance - Partie 2: Méthode à deux microphones pour le coefficient d'absorption acoustique normal et l'impédance de surface normale (ISO/DIS 10534-2:2022)

**Ta slovenski standard je istoveten z:** **prEN ISO 10534-2**

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**ICS:**

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| 17.140.01 | Akustična merjenja in blaženje hrupa na splošno | Acoustic measurements and noise abatement in general |

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# Acoustics — Determination of acoustic properties in impedance tubes —

## Part 2: **Two-microphone technique for normal sound absorption coefficient and normal surface impedance**

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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 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 10534-2 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*.

ISO 10534 currently consists of the following parts:

— Part 1: Method using standing wave ratio

— Part 2: 2-microphone technique for normal sound absorption coefficient and normal surface impedance

Annexes A and B form an integral part of this part of ISO 10534. Annexes C to G are for information only.



# Acoustics — Determination of acoustic properties in impedance tubes —

## Part 2: Two-microphone technique for normal sound absorption coefficient and normal surface impedance

## 1 Scope

This test method covers the use of an impedance tube, two microphone locations and a frequency analysis system for the determination of the sound absorption coefficient of sound absorbing materials for normal sound incidence. It can also be applied for the determination of the acoustical surface impedance or surface admittance of sound absorbing materials. As an extension, it can also be used to assess intrinsic properties of homogeneous acoustical materials such as their characteristic impedance, characteristic wavenumber, dynamic mass density and dynamic bulk modulus.

The test method is similar to the test method specified in ISO 10534-1[1] in that it uses an impedance tube with a sound source connected to one end and the test sample mounted in the tube at the other end. However, the measurement technique is different. In this test method, plane waves are generated in a tube by a noise source, and the decomposition of the interference field is achieved by the measurement of acoustic pressures at two fixed locations using wall-mounted microphones or an in-tube traversing microphone, and subsequent calculation of the complex acoustic transfer function and quantities reported in the previous paragraph. The test method is intended to provide an alternative, and generally much faster, measurement technique than that of ISO 10534-1[1].



Normal incidence absorption coefficients coming from impedance tube measurements are not comparable with random incidence absorption coefficients measured in reverberation rooms according to ISO 354.[2] The reverberation room method will (under ideal conditions) determine the sound absorption coefficient for diffuse sound incidence. However, the reverberation room method requires test specimens which are rather large. The impedance tube method is limited to studies at normal and plane incidence and requires samples of the test object which are of the same size as the cross-section of the impedance tube. For materials that are locally reacting only, diffuse incidence sound absorption coefficients can be estimated from measurement results obtained by the impedance tube method (see Annex E).

Through the whole document, a $e^{+j\omega t}$ time convention is used.

## 2 Terms, Definitions and symbols

For the purposes of this part of ISO 10534 the following definitions apply.

**2.1**
**sound absorption coefficient at normal incidence**
$\alpha_{\mathrm{n}}$
ratio of the sound power entering the surface of the test object (without return) to the incident sound power for a plane wave at normal incidence

Note 1 to entry: "Plane wave" here describes a wave whose value, at any moment, is constant over any plane perpendicular to its direction of propagation. "Normal incidence" describes the direction of the longest axis of the impedance tube.

**2.2**
**sound pressure reflection coefficient at normal incidence**
*r*
complex ratio of the reflected wave sound pressure amplitude to that of the incident wave in the reference plane for a plane wave at normal incidence

**2.3**
**reference plane**
cross-section of the impedance tube for which the reflection coefficient *r* or the impedance *Z* or the admittance *G* are determined and which is usually the surface of the test object, if flat

Note 1 to entry: The reference plane is assumed to be at $x = 0$.

**2.4**
**normal surface impedance**
*Z*
ratio of the complex sound pressure $p(x=0)$ to the normal component of the complex sound particle velocity $v(x=0)$ at an individual frequency in the reference plane defined as $x=0$. The particle velocity vector has a positive direction pointing towards the interior of the tested object. *Z* is expressed in newton second per cubic meter ($N.s.m^{-3}$)

**2.5**
**normal surface admittance**
*G*
inverse of the normal surface impedance *Z*. *G* is expressed in cubic meter per newton per second ($m^3.N^{-1}.s^{-1}$)



**2.6**
**wave number in air**
$k_0$
variable, expressed in radian per metre, defined by



$$k_0 = \omega / c_0 = 2\pi f / c_0$$

where

$\omega$ is the angular frequency;

$f$ is the frequency;

$c_0$ is the speed of sound in the air

Note 1 to entry: In general, the wave number is complex, so

$$k_0 = k'_0 - jk''_0$$

where

$k_{0'}$ is the real component $(k_0 = 2\pi / \lambda_0)$;

$\lambda_0$ is the wavelength in air;

$k_{0''}$ is the imaginary component which is the attenuation constant, in radian per metre.

**2.7**
**material characteristic wave number**
$k_c$
variable, expressed in radian per meter, defined by

$$k_c = \omega / c = 2\pi f / c = \omega \sqrt{p_{eq} / K_{eq}}$$

where

$c$ is the speed of sound inside the material;

$p_{eq}$ is the material dynamic mass density (defined in 2.9);

$K_{eq}$ is the material bulk modulus (defined in 2.10)

**2.8**
**material characteristic impedance**
$Z_c$
variable, expressed in newton. second per cubic metre, defined by

$$Z_c = \sqrt{p_{eq} K_{eq}}$$

**2.9**
**material dynamic mass density**
$p_{eq}$
describes the visco-inertial dissipation inside the tested material. The dynamic mass density can differ from the static (volume-averaged) value. It is expressed in kg.m$^{-3}$



**2.10**
**material dynamic bulk modulus**
$K_{eq}$
describes the thermal dissipation inside the tested material. The dynamic bulk modulus can differ from the static (volume-averaged) value. It is expressed in N.m$^{-2}$ (or equivalently in pascal)

**2.11**
**complex sound pressure**
$p$
frequency-domain spectrum of the sound pressure time signal

**2.12**
**cross spectrum**
$S_{12}$
product $p_2\ p_1{}^*$, determined from the complex sound pressures $p_1$ and $p_2$ at two microphone positions

Note 1 to entry: * means the complex conjugate.

**2.13**
**auto spectrum**
$S_{11}$
product $p_1\ p_1{}^*$, determined from the complex sound pressure $p_1$ at microphone position one

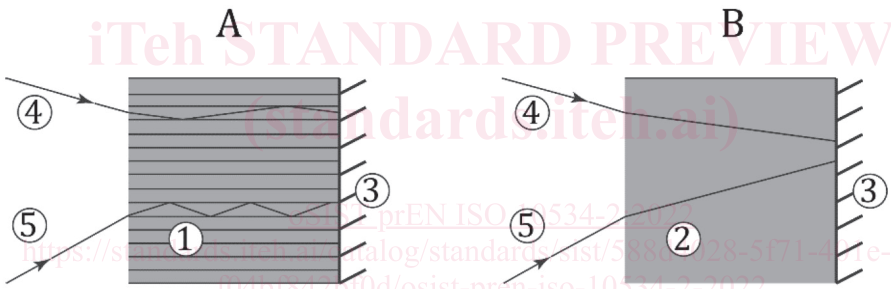
Note 1 to entry: * means the complex conjugate.

**2.14**
**transfer function**
$H_{12}$
transfer function from microphone position one to two, defined by the complex ratio $p_2 / p_1 = S_{12} / S_{11}$ or $S_{22} / S_{21}$, or $[(S_{12} / S_{11})(S_{22} / S_{21})]^{1/2}$

**2.15**
**calibration factor**
$H_c$
factor used to correct for amplitude and phase mismatches between the microphones

Note 1 to entry: See 7.5.2.

**2.16**
**local reaction**
a material for which the pressure and velocity fields at a given point on the surface are independent on the behaviour at other points of the surface is called a locally reacting material. This local reaction behavior infers specific properties for a material: its surface impedance is independent on the incidence angle of a plane wave impinging the material. Homogeneous honeycomb structures and perforated plates are examples of possible locally reacting materials (see Figure 1, left). Note that for a locally reacting material, its absorption coefficient depends on the angle of incidence as its reflection coefficient does as well






**Key**

1 locally reacting material sample
2 non-locally reacting material sample
3 rigid & impervious backing
4 plane wave impinging the sample
5 plane wave impinging the sample with a different angle
A locally reacting material sample
B non-Locally reacting material sample

**Figure 1 — Propagation of plane waves inside a locally reacting material sample and comparison to a non-locally reacting material sample**

**2.17**
**bulk or extended reaction**
the assumption of bulk or extended reaction implies that the reaction inside the material does not occur only normal to the surface. The reaction in each point is hence dependent on the reaction of the neighbouring points. Examples of materials experiencing bulk reactions are foams made of multiple pores and fibrous with fibres not parallel to each other's (see Figure 1, right)

## 3 Principle

The test sample is mounted at one end of a straight, rigid, smooth and airtight impedance tube. Plane waves are generated in the tube by a sound source emitting a signal such as a random noise, pseudo-random sequence, or a deterministic signal such as a chirp signal, and the sound pressures are measured at two locations near to the sample. The complex acoustic transfer function of the two microphone signals is determined and used to compute the normal-incidence complex reflection coefficient (see

Annex C), the normal-incidence absorption coefficient, and the normal surface impedance of the test material. From two distinct measurements, the intrinsic properties of the material (characteristic wave number, characteristic impedance, dynamic mass density and dynamic bulk modulus) can be assessed (see Annex G) assuming this material is homogeneous.

The quantities are determined as functions of the frequency (or frequency bands as detailed in ISO 266[3]) with a frequency resolution which is determined from the sampling frequency and the record length of the digital frequency analysis system used for the measurements. The usable frequency range depends on the lateral dimensions or diameter of the tube and the spacing between the microphone positions. An extended frequency range may be obtained from the combination of measurements with different lateral dimensions (or diameter) and spacings.

The measurements may be performed by employing one of two techniques:

1) two-microphone method (using two microphones in fixed locations);

2) one-microphone method (using one microphone successively in two locations).

Technique 1: requires a pre-test or in-test correction procedure to minimize the amplitude and phase difference characteristics between the microphones; however, it combines speed, high accuracy, and ease of implementation. Technique 1 is recommended for general test purposes.

Technique 2: has particular signal generation and processing requirements and may necessitate more time; however, it eliminates phase mismatch between microphones and allows the selection of optimal microphone locations for any frequency. Technique 2 is recommended for measurements with higher precision, and its requirements are described in more detail in Annex B.



# 4 Test equipment



## 4.1 Construction of the impedance tube

The apparatus is essentially a tube with a test sample holder at one end and a sound source at the other. Microphone ports are usually located at two or three locations along the wall of the tube (depending on the chosen microphone spacing), but variations involving a centred mounted microphone or probe microphone are possible.

The impedance tube shall be straight with a uniform cross-section (diameter or cross dimension within ±0,2 %) and with rigid, smooth, non-porous walls without holes or slits (except for the microphone positions) in the test section. The walls shall be heavy and thick enough so that they are not excited to vibrations by the sound signal and show no vibration resonances in the working frequency range of the tube. For metal walls, a thickness of about 5 % of the diameter is recommended for circular tubes. For rectangular tubes the corners shall be made rigid enough to prevent distortion of the side wall plates. It is recommended that the side wall thickness be about 10 % of the cross dimension of the tube. Tube walls made of concrete shall be sealed by a smooth adhesive finish to ensure air tightness. The same holds for tube walls made of wood; these should be reinforced and damped by an external coating of steel or lead sheets.

The shape of the cross-section of the tube is arbitrary, in principle. Circular or rectangular (if rectangular, then preferably square) cross-sections are recommended.

If rectangular tubes are composed of plates, care shall be taken that there are no air leaks (e.g. by sealing with adhesives or with a finish). Tubes should be sound and vibration isolated against external noise or vibration.

## 4.2 Working frequency range

The working frequency range is

$$f_\mathrm{l} < f < f_\mathrm{u} \tag{1}$$

where

$f_\mathrm{l}$ is the lower working frequency of the tube;

$f$ is the operating frequency;

$f_\mathrm{u}$ is the upper working frequency of the tube.

$f_\mathrm{l}$ is limited by the accuracy of the signal processing equipment and the spacing between the 2 microphone positions.

$f_\mathrm{u}$ is chosen to avoid the occurrence of non-plane wave mode propagation. The condition for $f_\mathrm{u}$ is:

$$d < 0{,}58\ \lambda_\mathrm{u} :\ f_\mathrm{u} \cdot d < 0{,}58\ c_0 \tag{2}$$

for circular tubes with the inside diameter $d$ in metres and $f_\mathrm{u}$ in hertz.

$$d < 0{,}50\ \lambda_\mathrm{u} :\ f_\mathrm{u} \cdot d < 0{,}50\ c_0 \tag{3}$$



for rectangular tubes with the maximum side length d in metres; $c_0$ is the speed of sound in metres per second given by Equation (5).

The spacing $s$ in metres between the microphones shall be chosen to avoid singularities when the distance of the two microphone positions is equal to a multiple of half the operating wavelength. The first singularity is avoided when ensuring that



$$f_\mathrm{u} \cdot s < 0{,}45\ c_0 \tag{4}$$

The lower frequency limit is dependent on the spacing between the microphones and the accuracy of the analysis system but, as a general guide, the microphone spacing should exceed 1,5 % of the wavelength corresponding to the lower frequency of interest, provided that the requirements of Equation (4) are satisfied. A larger spacing between the microphones enhances the accuracy of the measurements for these low frequencies but reduces the value of the upper working frequency.

Different microphone spacings can be used to cover a wider frequency range than the one allowed for a single spacing. In this case, the working frequency ranges shall overlap by about one octave (as described in ISO 266, "Acoustics — Preferred frequencies"). The averaging technique used to obtain the averaged and combined result should be at least mentioned.

Different impedance tubes can also be used to cover a wider frequency range than the one allowed for a single tube (see section 9.i).

## 4.3 Length of the impedance tube

The tube should be long enough to cause plane wave development between the source and the sample. Microphone measurement points shall be in the plane wave field.

The loudspeaker generally will produce non-plane waves besides the plane wave. They will die out within a distance of about three tube diameters or three times the maximum lateral dimensions of rectangular tubes for frequencies below the lower cut-off frequency of the first higher mode. Thus, it is recommended that microphones be located no closer to the source than suggested above.