INTERNATIONAL STANDARD

ISO 7235

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Acoustics — Laboratory measurement procedures for ducted silencers and air-terminal units — Insertion loss, flow noise and total pressure loss

Acoustique — Modes opératoires de mesure en laboratoire pour silencieux en conduit et unités terminales — Perte d'insertion, bruit d'écoulement et perte de pression totale

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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 7235 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This second edition cancels and replaces the first edition (ISO 7235:1991), which has been technically revised.

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Introduction

This International Standard specifies the substitution method for determining the insertion loss of ducted silencers and a method for determining the transmission loss of air-terminal units.

In the substitution method, the sound pressure level of the transmitted wave is first determined for the test object and then when the test object has been replaced by the substitution duct. The sound pressure level of the transmitted wave can be measured

- in a reverberation room,
- in a test duct after the silencer, or
- in an essentially free field.

The methods are listed in order of preference.

The acoustic performance of silencers depends on the modal composition of the sound field at the inlet and on reflections at the outlet side, on flanking transmission and on level differences between signals and flow noise (or regenerated sound).

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This International Standard describes configurations at the inlet side providing for a predominant fundamental mode that suffers the least attenuation. For the outlet side, it describes anechoic terminations and measurement procedures which are not sensitive to reflections or which allow for specified corrections. Furthermore, this International Standard gives guidance on the suppression of flanking transmission and noise signals.

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The transmission loss of an air-terminal unit is determined from the results of measurements in a reverberation room and theoretical reflection coefficients of a substitution duct.

The insertion loss of a silencer is generally affected by the airflow. The insertion loss is therefore preferably measured with superimposed airflow if the silencer is to be used in ducts with high flow velocity.

For absorptive silencers where the maximum internal flow velocity falls short of 20 m/s, the flow will hardly have an effect on the insertion loss. In practice, non-uniform flow distributions will occur. Therefore, the limit velocity of 20 m/s may correspond to a design velocity of 10 m/s to 15 m/s.

An airflow through a silencer regenerates noise. This flow noise (or regenerated sound) establishes the lowest sound pressure level that can be achieved after the silencer. It is, therefore, necessary to know the sound power level of the flow noise (or regenerated sound) behind the silencer. This is preferably determined in a reverberation room connected to the object via a transmission element.

In accordance with this International Standard, the total pressure loss of a silencer to be used with flow is to be determined. It is, therefore, useful to equip the test facility with the instruments and devices necessary for the determination of the total pressure loss.

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Acoustics — Laboratory measurement procedures for ducted silencers and air-terminal units — Insertion loss, flow noise and total pressure loss

1 Scope

This International Standard specifies methods for determining

- the insertion loss, in frequency bands, of ducted silencers with and without airflow,
- the sound power level, in frequency bands, of the flow noise (or regenerated sound) generated by ducted silencers,
- the total pressure loss of silencers with airflow, and
- the transmission loss, in frequency bands, of air-terminal units.

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The measurement procedures are intended for laboratory measurements at ambient temperature. Measurements on silencers *in situ* are specified in ISO 11820.

It is to be noted that the results determined in a laboratory according to this International Standard will not necessarily be the same as those obtained *in situ* (installation), as different sound and flow fields will yield different results. For example, the pressure loss will be lower under laboratory conditions than *in situ*, but will be comparable between different laboratories.

This International Standard is applicable to all types of silencer including silencers for ventilating and air-conditioning systems, air intake and exhaust of flue gases, and similar applications. Other passive air-handling devices, such as bends, air-terminal units or T-connectors, can also be tested using this International Standard.

This International Standard is not applicable to reactive silencers used for motor vehicles.

NOTE 1 Annex A specifies the sound field excitation equipment. Annex B gives requirements for the transition element. Annex C gives details of duct walls and limiting insertion loss. Annex D specifies how to convert one-third-octave band attentuation values to octave band values. Annex E gives requirements for measurements on large parallel-baffle silencers. Annex F specifies a test of longitudinal attenuation. Annex G gives guidelines on anechoic terminations and Annex H shows examples of measurement arrangements.

NOTE 2 Acoustic testing of air-terminal devices and fan-coil units is to be carried out as described for air-terminal units.

NOTE 3 Sound power measurements on air-terminal units are specified in ISO 5135. Measurements of the pressure loss of air-terminal units are described in EN 12238, EN 12239 and EN 12589.

2 Normative references

The following referenced documents are indispensable for the application 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 3741:1999, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Precision methods for reverberation rooms*

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ISO 3746, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Survey method using an enveloping measurement surface over a reflecting plane*

ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 1: General principles and requirements*

ISO 5221, *Air distribution and air diffusion — Rules to methods of measuring air flow rate in an air handling duct*

ISO 9614-3, *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 3: Precision method for measurement by scanning*

IEC 60651:2001, *Sound level meters*

IEC 60804:2000, *Integrating-averaging sound level meters*

IEC 60942:1997, *Electroacoustics — Sound calibrators*

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

3 Terms and definitions

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

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3.1
insertion loss
D_i
⟨of the test object⟩ reduction in the level of the sound power in the duct behind the test object due to the insertion of the test object into the duct in place of a substitution duct, given by the equation

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$$D_i = L_{WII} - L_{WI} \quad (1)$$

where

L_{WI} is the level of the sound power in the frequency band considered, propagating along the test duct or radiating into the connected reverberation room when the test object is installed;

L_{WII} is the level of the sound power in the frequency band considered, propagating along the test duct or radiating into the connected reverberation room when the substitution duct replaces the test object.

NOTE 1 The insertion loss is expressed in decibels (dB).

NOTE 2 For measurements according to this International Standard, the insertion loss of a silencer equals its transmission loss.

3.2
transmission loss
D_t
⟨of an air-terminal unit⟩ difference between the levels of the sound powers incident on and transmitted through the test object

NOTE 1 The transmission loss is expressed in decibels (dB).

NOTE 2 Adapted from ISO 11820:1996.

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3.3
face velocity
v_f
velocity in front of the test object

$$v_f = \frac{q_V}{S_1} \quad (2)$$

where

q_V is the volume flow rate, in cubic metres per second (m^3/s);

S_1 is the inlet (or face) cross-sectional area of the test object, in square metres (m^2)

NOTE The face velocity is expressed in metres per second (m/s).

3.4
total pressure loss
Δp_t
⟨of the test object⟩ difference between the total pressures upstream and downstream of the test object

NOTE The total pressure loss is expressed in pascals (Pa).

3.5
total pressure loss coefficient
ζ
total pressure loss divided by the face velocity pressure upstream of the test object, given by the formula

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$$\zeta = \frac{\Delta p_t}{\frac{1}{2}\rho_1 v_f^2} \quad (3)$$

where

Δp_t is the total pressure loss, in pascals (Pa);

ρ_1 is the air density upstream of the silencer, in kilograms per cubic metre (kg/m^3);

v_f is the face velocity, in metres per second (m/s) (see 3.3)

3.6
front
position relative to the direction of the sound propagation of the sound signal to be measured, corresponding to the “source side”

3.7
behind
position relative to the direction of the sound propagation of the sound signal to be measured, corresponding to the “receiving side”

3.8
test duct
straight, rigid duct of constant cross section in front of and behind the test object

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3.9
transition
duct element which connects two duct sections with different duct cross sections to each other

NOTE Transitions which are part of a silencer as supplied by the manufacturer/supplier are considered part of the test object.

3.10
anechoic termination
device intended to reduce sound reflections at the receiving-side end of the test duct

3.11
transmission element
connection from the test duct behind the test object to a reverberation room, transmitting a certain fraction of the sound energy from the duct into the room

3.12
substitution duct
rigid, non-absorbing duct element and having the same length and the same connecting cross sections as the test object

3.13
reverberation room
test room meeting the requirements of ISO 3741

[ISO 3741:1999]

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3.14
regenerated sound
flow noise
noise caused by the flow conditions in the test object

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NOTE Adapted from ISO 14163:1998.

3.15
background noise level
sound pressure level at the indicating instrument when measurements are made with the substitution duct in place and the loudspeaker is switched off

NOTE 1 The background noise level is expressed in decibels (dB).

NOTE 2 Adapted from ISO 11200:1995.

NOTE 3 The main elements in background noise are

- flow noise from the fan,
- flow noise generated at the microphone,
- flow noise from the duct system,
- structure-borne sound from the fan propagating along the duct walls to the measurement position,
- airborne sound radiated from the fan or from the loudspeaker equipment into the test room and transmitted through the duct walls to the microphone, and
- electrical noise in the measurement equipment.

NOTE 4 Flanking transmission of sound from the loudspeaker or of flow noise generated by the test object is not part of the background noise, but determines the limiting insertion loss.

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3.16
reflection coefficient
r
ratio of the reflected sound pressure amplitude to the sound pressure amplitude of the sound wave incident on the reflecting object

NOTE Adapted from ISO 5136:1990.

3.17
frequency range of interest
one-third-octave bands with centre frequencies from 50 Hz to 10 000 Hz

NOTE For certain applications, it may be sufficient to measure in the frequency range between 100 Hz and 5 000 Hz.

3.18
limiting insertion loss
maximum insertion loss which can be determined in a given test installation without flow

NOTE 1 The limiting insertion loss is expressed in decibels (dB).

NOTE 2 The limiting insertion loss is generally determined by the flanking transmission along the duct walls.

3.19
test object
complete silencer, as supplied by the manufacturer/supplier, one or several parallel baffles installed in a substitution duct, or an air-terminal unit, ready for installation in the test facility, including its housing and its inlet and outlet openings to be connected to ducts

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NOTE 1 Examples of silencers are given in Figure 1 and Annex E. Other elements to which the method of this International Standard is applicable are listed in Clause 1.

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NOTE 2 For “parallel baffles”, the term “splitters” is also common.

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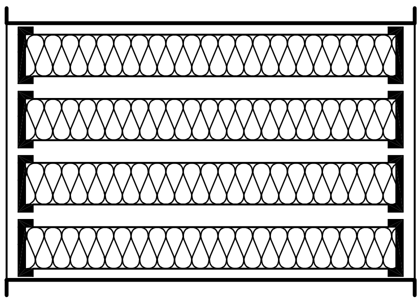
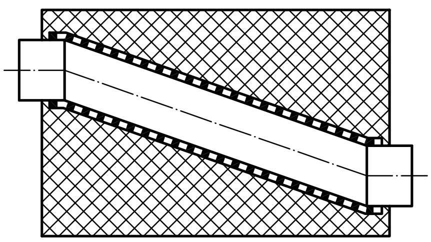


a) Parallel-baffle silencer without transitions



b) Off-set silencer

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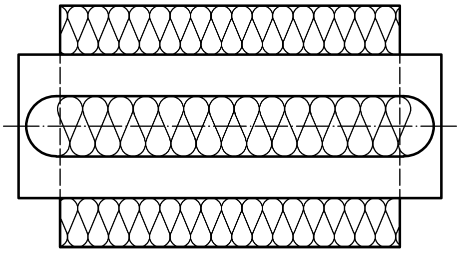
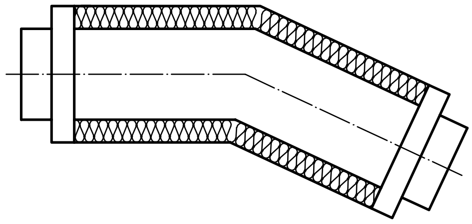
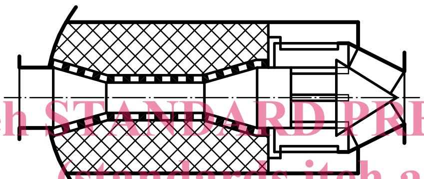


c) Circular silencer with concentric pod



d) Flexible silencer



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e) Silencer with spark arrestor

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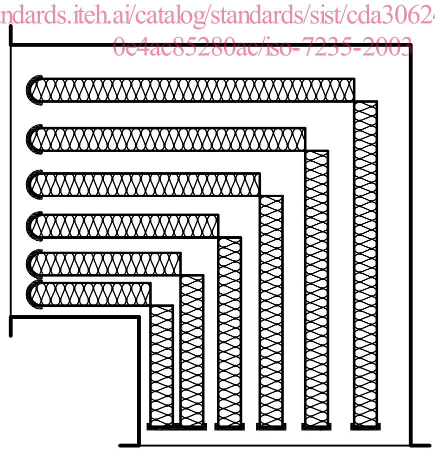

f) Elbow silencer

NOTE A centreline is only drawn for test objects with a rotationally symmetrical airway cross section.

Figure 1 — Examples of silencers

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4 Symbols

Symbols are listed in Table 1. The meanings of indices used in this International Standard are explained in Table 2.

Table 1 — Symbols

Symbol	Definition	Unit	Reference
C	difference in level between the sound power radiated into the reverberation room and the average sound pressure level in the reverberation room	dB	6.4
c	speed of sound	m/s	5.2.2.3, B.3
D_a	propagation loss	dB/m	Annex F
D_i	insertion loss	dB	3.1, 6.2, 6.3, A.4
D_t	transmission loss	dB	3.2, 6.3
D_{td}	transmission loss of open end of test object	dB	6.3, 6.4, B.3
d	diameter of duct	m	5.2.2.3, G.1.4
d_e	equivalent diameter	m	6.5.2.2.1
f	frequency	Hz	B.3
f_C	cut-on frequency of higher-order modes in the duct	Hz	B.2.2, G.2.2, G.2.3.7
f_{Cd}	cut-on frequency of higher-order modes in duct with circular cross section	Hz	5.2.2.3
f_{CH}	cut-on frequency of higher-order modes in duct with rectangular cross section	Hz	5.2.2.3
H	height (of silencer or model)	m	5.2.2.3, Annex E
l_{min}	minimum length of transition	m	5.4.2.3, Figure 7
L_p	sound pressure level	dB	6.2, 6.3, 6.4
L_W	sound power level	dB	3.1, 6.4
p	pressure	Pa	Figure 6, Table 4, 6.5.2.1, 6.5.2.2.1, 6.5.2.2.2, Figure 9, 6.5.2.2.3
q_m	mass flow rate	kg/s	5.4.2.2, 6.5.1
q_V	volume flow rate	m^3/s	3.3, Table 3, 6.5.1, 6.5.2.1, 6.5.2.2.1, 6.5.2.2.2, Figure 9, 6.5.2.2.3
R	specific gas constant for air, R = 287 N·m/kg·K	N·m/kg·K	6.5.2.1, 6.5.2.2.3
r	reflection coefficient	1	3.16, 5.4.2.6, Table 5, B.2.1, B.3, G.2.1, G.2.3.6
r_t	turning radius	m	5.2.2.4.3, Figure 4
S	cross-sectional area, general	m^2	6.5.2.1, B.3, Annex E

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Table 1 — Symbols *(continued)*

Symbol	Definition	Unit	Reference
S_1	test duct cross-sectional area, inlet	m^2	3.3, Figure 6, Figure 7, 6.5.2.1, 6.5.2.2.2, 6.5.2.2.3
S_2	test duct cross-sectional area, outlet	m^2	Figure 7, 6.5.2.1
S_T	test object cross-sectional area	m^2	Figure 6
s	gap width in baffle silencer	m	Annex E
t_b	baffle thickness	m	Figure 6, Annex E
v_f	face velocity	m/s	3.3, 3.5
w	width (of silencer or model)	m	Annex E
ΔL	difference between maximum and minimum sound pressure levels of a standing wave in the duct	dB	B.2.1, G.2.1, G.2.3.6
Δp	pressure difference	Pa	3.4, 3.5, 6.5.2.1, 6.5.2.2.2, Figure 6
ζ	total pressure loss coefficient	1	3.5, 6.5.2.1, 6.5.2.2.2, 6.5.2.2.3, 7.8
θ_1	temperature upstream of test object	°C	6.5.2.1, 6.5.2.2.1, 6.5.2.2.3
ρ_1	air density upstream of test object	kg/m^3	3.5, 6.5.1, 6.5.2.2.3
σ_{Ri}	standard deviation of reproducibility of insertion loss	dB	7.9, Table 7
σ_{RI}	standard deviation of reproducibility of intensity level	dB	7.9, Table 7
σ_{Rt}	standard deviation of reproducibility of transmission loss	dB	7.9, Table 7
Ω	solid angle of sound radiation at the duct end	sr	B.3

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Table 2 — Indices

Index	denotes
a	ambient
d	dynamic
i	insertion
I	intensity
n	referring to the airflow rate in the middle of the range of interest
R	receiving-side equipment
R	reproducibility
S	sound-source equipment
s	static
t	transmission
T	test object
tot	total
I	with test object installed
II	with test object replaced by substitution duct

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5 Test facilities and requirements for instrumentation

5.1 Purpose and types of test facilities

Different test facilities are specified, depending on the task, as follows.

a) Acoustic testing without airflow is applied to determine the insertion loss of a complete silencer ready for installation in the test facility, which can be replaced by a substitution duct (or a set of baffles in the substitution duct which shall have a minimum height of one baffle thickness) when the effect of airflow on the test result is negligible (e. g. for absorptive silencers with an airway flow velocity of less than 20 m/s).

b) Acoustic testing without airflow is also applied to determine the transmission loss of an air-terminal unit, which may be mounted inside or outside a reverberation room and may contain a flow-rate controller (an aerodynamically, electrically or pneumatically actuated damper) and a distribution box with spigots and dampers.

c) Flow testing is applied to determine the total pressure loss of the test object and the sound power level of flow noise (or regenerated sound).

d) Dynamic testing with airflow is applied to determine the insertion loss of a complete silencer or a set of baffles when the effect of airflow on the test result is not negligible (e. g. for certain types of reactive silencers and for high flow velocities).

Acoustic testing (as compared to dynamic testing) allows for easier connection of the sound source to the test object and does not require high sound power levels to overcome the level of flow noise (or regenerated sound). Major requirements for flow and dynamic testing result from the need for a quiet inflow.

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5.2 Equipment for acoustic testing of silencers

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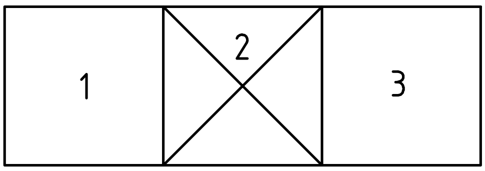
5.2.1 Equipment sets

The test set-up for acoustic testing comprises (see Figure 2)

— the sound source equipment (see 5.2.2),

— the test object, and

— the receiving-side equipment (see 5.2.4).



Key

1 sound-source equipment

2 test object

3 receiving-side equipment

Figure 2 — Test set-up for acoustic testing (schematic)

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