ISO/FDIS 17201-4~~:2025(en)~~

ISO/TC 43/SC 1~~/WG 51~~

Secretariat: DIN

Date: 2025~~-03-14~~-xx

Acoustics — Noise from shooting ranges —

Part 4: Calculation of projectile sound

Acoustique — Bruit des stands de tir —

Partie 4: Calcul du bruit du projectile

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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.

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 document 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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This document was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 211, *Acoustics*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 17201-4:2006), which has been technically revised.

The main changes are as follows:

— restructure of the document into new clauses: Projectile sound, Source description, Sound exposure level at the receiver, and Uncertainty;

— separation of source and propagation terms;

— inclusion (from ISO 17201-2) and update of the source level for non-streamlined projectiles;

— expansion of the Clause on uncertainty;

— addition of ~~Annex B~~Annex B on ballistic trajectories;

— addition of ~~Annex C~~Annex C on projectile velocity change;

— addition of ~~Annex D~~Annex D with informative examples.

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A list of all parts in the ISO 17201 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.www.iso.org/members.html.

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Introduction

Shooting sound registered around shooting ranges consists in general of three components: muzzle blast sound, impact sound and projectile sound. This document deals solely with the projectile sound from supersonic projectiles. It specifies a method for calculating the source sound exposure level of projectile sound. It also provides a method for calculating the propagation of projectile sound, accounting for its distinct characteristics that set it apart from the propagation of sound originating from other sources.

This document is intended for calibres of less than 20 mm but can also be used for larger calibres.

Projectile sound is described as originating from a certain point on the projectile trajectory, the "source point".

The source sound exposure level is calculated from the geometric properties and the speed of the projectile along its trajectory. Methods are given on how the sound exposure level at a receiver location is to be calculated from this source sound exposure level, taking into account geometrical attenuation, atmospheric absorption and attenuation and frequency shift due to non-linear effects. In addition, the effects on the sound exposure level due to the decrease of the projectile speed and atmospheric turbulence are taken into account.

In a restricted region, the Mach region (region II – see ~~4.2),~~4.2), the projectile sound exposure level is significant compared to the muzzle blast sound exposure level. Outside this region only diffracted or scattered projectile sound is received, with considerably lower levels than in this Mach region. Projectile sound behind the Mach region (region I) is negligible compared to muzzle sound, except for contributions due to reflections from other regions. In this document, a computational scheme for the levels in regions II and III is provided. The levels in region III are typically 10 dB to 15 dB lower compared to region II.

Two computational methods are given to be able to calculate the projectile sound for streamlined and non-streamlined projectiles such as pellets. Default values of parameters used in this document are given for a temperature of 10 °C, 80 % relative humidity, and a pressure of 1 013 hPa. ~~Annex A~~Annex A can be used for calculations for other atmospheric conditions. For calibres <20 mm, the source spectrum is dominated by high frequency components. As air absorption is rather high for these frequency components, calculations are performed in one-third octave bands, in order to obtain more accurate results.

For projectiles with a speed just above the speed of sound the computational methods are less accurate. Guidance is given how to deal with this increased uncertainty.

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Acoustics — Noise from shooting ranges — ~~Part 4: Calculation of projectile sound~~

Part 4:
Calculation of projectile sound

1 Scope

This document specifies computational methods for determining the acoustical source level of projectile sound and its one-third octave band spectrum, expressed as the sound exposure level for nominal mid band frequencies from 12,5 Hz to 10 kHz. It also specifies a method on how to use this source level to calculate the sound exposure level at a receiver position.

Results obtained with this document can be used as a basis for assessment of projectile sound from shooting ranges. Additionally, the data can be used to determine sound emission or immission from different types of ammunition and weapons. The prediction methods are applicable to outdoor conditions and straight projectile trajectories. Two computational methods are given to determine the acoustical source level: one for streamlined projectile shapes and one for non-streamlined shapes, such as pellets.

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.

~~<std>ISO 80000-8, *Quantities and units — Part 8: Acoustics*</std>~~

ISO 80000-8, *Quantities and units — Part 8: Acoustics*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 80000-~~-~~8 and the following apply.

ISO~~-~~ and IEC maintain terminology databases for use in standardization at the following addresses:

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

— ~~—~~IEC Electropedia: available at ~~https://www.electropedia.org/~~https://www.electropedia.org/

3.1 ~~3.1~~
streamlined projectile
projectile that has a shape that can be described as a body of revolution of which the first derivative of the cross-sectional area $A(x)$ at a distance x behind the nose of the body is continuous for $0 < x < l_p$

Note 1 to entry: For the definition of effective projectile length, l_p, see ~~3.3.~~3.3.

3.2 ~~3.2~~
non-streamlined projectile
projectiles that have a body different from *streamlined projectiles* ~~(3.1)~~(3.1)

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Note 1 to entry—: These can be multi part projectiles, such as shotgun pellets, or single part projectiles with a non-streamlined form, such as shotguns slugs (see Figure 1).Figure 1).

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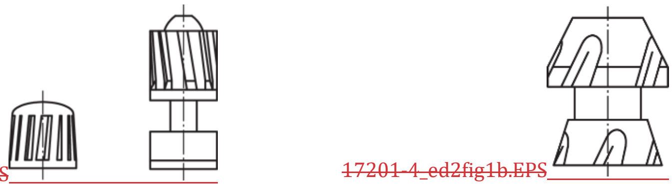

Figure 1 — Examples of non-streamlined projectiles

Note 2 to entry—: For the definition of effective projectile length, l_p, see 3.3.3.3.

3.3 3.3

effective projectile length

l_p

distance between the nose and the cross-section of streamlined projectiles where it reaches the maximum diameter of the projectile

Note 1 to entry—: The effective length of the projectile (see Figure 2)Figure 2) is measured along the length-axis of the projectile and is expressed in metres (m).

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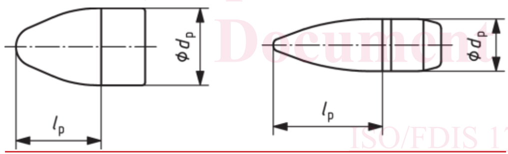

Key

l_p	effective projectile length, expressed in metres (m)
d_p	maximum diameter of projectile, expressed in metres (m)

Figure 2 — Effective projectile length

Note 2 to entry—: For non-streamlined projectiles: The distance between the two points on the longitudinal axis of the projectile at which the radius of the projectile changes the most is used as the effective length for non-streamlined projectiles. If this is not applicable due to the special shape of the projectile other methods shall be used to determine the effective length, e.g. via sound measurements. For projectiles consisting of pellets as used mainly in shotguns, the effective length is set to the diameter of the barrel of the shotgun.

3.4 3.4

N-wave

idealized waveform of a sound having a pressure variation with time described by a sudden initial increase to a maximum followed by a linear decay to a minimum and ending with a sudden increase back to the initial sound pressure

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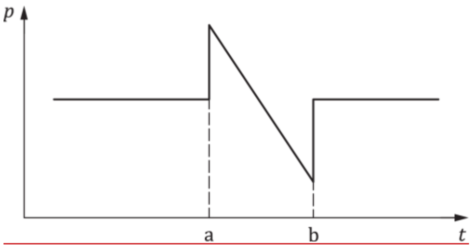

Figure 3 — Assumed N-shaped waveform for sound of a supersonic projectile at 1 m from the source point on its projectile's trajectory. The duration is the time between a and b.

Note 1 to entry: Measurements show deviation from the idealized N-wave that is increasing with distance (see Figure 3).Figure 3).

3.5

3.5 characteristic

duration time

T_c

duration between two pressure increases of the *N-wave* (3.4)(3.4)

Note 1 to entry: See points a and b in Figure 3Figure 3.

Note 2 to entry: The duration is expressed in seconds (s).

Note 3 to entry: T_c will change along the sound propagation path resulting from non-linear acoustic effects.

3.6 3.6

characteristic frequency

f_c

inverse of the duration time, T_c

$$f_c = \frac{1}{T_c}$$

$$f_c = \frac{1}{T_c}$$

Note 1 to entry: The characteristic frequency is expressed in hertz (Hz).

3.7 3.7

co-ordinate system (*x*, *y*)

plane co-ordinate system describing geometry, where the X-axis denotes the line of fire with $x = 0$ at the muzzle, and the y-axis measures the perpendicular distance from the line of fire in any plane around the line of fire

Note 1 to entry: The sound field of projectile sound is rotational symmetric around the line of fire.

Note 2 to entry: The co-ordinates are given in metres (m).

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3.8 3.8
coherence distance
R_{coh}
distance between the *source point* (3.11)(3.11) on the projectile trajectory and a receiver beyond which the contribution to the sound from different parts of the trajectory are incoherent due to atmospheric turbulence

Note 1 to entry: The coherence distance is expressed in metres (m).

3.9 3.9
Mach number
M
ratio of the projectile speed to the local sound speed

3.10 3.10
source sound exposure level
$L_{E,s}$
sound exposure level expected at a distance of 1 m from the *source point* (3.11)(3.11)

Note 1 to entry: The source sound exposure level is expressed in decibels (dB).

Note 2 to entry: The reference distance of 1 m is defined in the direction of the receiver and not perpendicular to the trajectory.

3.11 3.11
source point
point where a line from the receiver perpendicular to the wave front of the projectile sound intersects the projectile trajectory

Note 1 to entry: The projectile radiates sound along the whole trajectory and is therefore in principle a line source. In this document, a source point is used to represent the position of the trajectory (see Formula (9)).Formula (9)).

3.12 3.12
projectile launch speed
v_{p0}
speed of the projectile as it leaves the muzzle

Note 1 to entry: The muzzle velocity is expressed in metres per second (m/s).

3.13 3.13
projectile speed
v_p
speed of the projectile along the trajectory

Note 1 to entry: The projectile speed is expressed in metres per second (m/s).

Note 2 to entry: Published data on the projectile speed as a function of distance refer to air density at sea level. For other elevations above sea level, changes of density shall be taken into account.

3.14 3.14
reference sound speed
c_{ref}
adiabatic sound speed averaged over a period of at least 10 min

Note 1 to entry: The reference sound speed is expressed in metres per second (m/s).

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3.15 ~~3.15~~
fluctuating effective sound speed
sum of the instantaneous adiabatic sound speed and the instantaneous horizontal wind velocity component in the direction of the sound propagation

Note 1 to entry: The fluctuating effective sound speed is expressed in metres per second (m/s).

3.16 ~~3.16~~
standard deviation of the fluctuating acoustical index of refraction
μ_0
standard deviation of the ratio of the *reference sound speed* ~~(3.14)~~(3.14) to the *fluctuating effective sound speed* ~~(3.15)~~(3.15)

Note 1 to entry: In accordance with Reference ~~[3]~~[3] a value of $\mu_0^2 = 10^{-5}$ is used within the context of this document [see ~~Formula (20)]~~.Formula (20)].

3.17 ~~3.17~~
projectile speed change
κ
local change of *projectile speed* ~~(3.13)~~(3.13) along the trajectory per length unit of trajectory

Note 1 to entry: The speed change is expressed in reciprocal seconds [(m/s per m) = 1/s].

Note 2 to entry: It is negative for non-self-propelled projectiles.

4 Projectile sound

4.1 General

When a projectile travels at supersonic speed, it generates a shock wave with a cone-shaped wave front originating from its nose. This is shown in ~~Figure 3~~Figure 3 for a constant projectile speed. However, as the projectile speed decreases along its trajectory, the wave front becomes curved. The area around the trajectory can be divided into three regions, each requiring different methods to calculate sound levels. This is explained in ~~4.2~~.4.2.

The time-history of the shock wave has the shape of the letter N and is therefore referred to as an N-wave. The spectrum of this N-wave can be calculated as detailed in ~~4.3~~.4.3.

~~Clause 5~~5 outlines the calculation of the source sound exposure level for both streamlined and non-streamlined projectiles.

~~In Clause 6,~~In 6, a method is described to calculate the sound exposure level of projectile sound at a receiver position, taking into account several attenuation terms that are subtracted from the source sound exposure level.

NOTE For the calculation of projectile sound on ballistic trajectories see ~~Annex B~~.Annex B.

4.2 Regions

Three regions (I, II and III) are distinguished around the trajectory to describe projectile sound (see ~~Figure 4)~~.Figure 4). In regions I and III sound exposure levels are considerably lower than in region II. In this document, a computational scheme for the sound exposure levels in regions II and III is provided. The levels in region I are negligible in comparison to the muzzle blast. The projectile speed is locally approximated by a linear function of the distance x along the projectile trajectory, according to ~~Formula (1)~~:Formula (1):

$$v_p(x) = v_{p0} + \kappa x \quad (1)$$

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The boundaries of region II are described with the angles ξ_0 and ξ_e, shown in Figure 4.Figure 4. These angles are given by Formula (2):Formula (2):

$$\xi_0 = \arccos\left(\frac{c_{am}}{v_{p0}}\right) \quad \text{and} \quad \xi_e = \arccos\left(\frac{c_{am}}{v_{pe}}\right) \qquad (2)$$

$$\xi_0 = \arccos\left(\frac{c_{am}}{v_{p0}}\right) \quad \text{and} \quad \xi_e = \arccos\left(\frac{c_{am}}{v_{pe}}\right) \qquad (2)$$

where

v_{pe} is the projectile speed at the end of the trajectory, in metres per second (m/s);

c_{am} is the speed of sound in metres per second (m/s).

The speed of sound is a function of the absolute temperature of the ambient air, T_{am}, in Kelvin and is given by Formula (3):Formula (3):

$$c_{am} = c_{ref}\left(\frac{T_{am}}{T_{ref}}\right)^{1/2} \qquad (3)$$

$$c_{am} = c_{ref}\left(\frac{T_{am}}{T_{ref}}\right)^{1/2} \qquad (3)$$

where

T_{ref} = 283,15 K (10 °C);

c_{ref} = 337,6 m/s (the speed of sound at T_{ref}).

When the projectile speed along the trajectory decreases below the speed of sound, the angle ξ_e becomes zero; the region III vanishes in this case.

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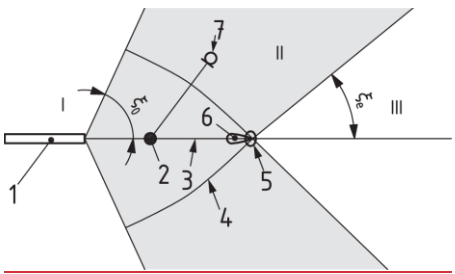

Key

1	weapon	5	target
2	source point	6	projectile
3	projectile trajectory	7	receiver
4	wavefront		

Figure 4 — Three regions for describing the sound of a projectile

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