INTERNATIONAL STANDARD

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Acoustics — Noise from shooting ranges —

Part 4: Prediction of projectile sound

Acoustique — Bruit des stands de tir —

Partie 4: Estimation du bruit du projectile

Reference number
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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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Contents

Page

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.

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 17201-4 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

ISO 17201 consists of the following parts, under the general title *Acoustics — Noise from shooting ranges*:

— *Part 1: Determination of muzzle blast by measurement*

— *Part 2: Estimation of muzzle blast and projectile sound by calculation*

— *Part 4: Prediction of projectile sound*

The following parts are under preparation:

— *Part 3: Guidelines for sound propagation calculation*

— *Part 5: Noise management*

The initiative to prepare a standard on impulse noise from shooting ranges was taken by AFEMS, the Association of European Manufacturers of Sporting Ammunition, in April 1996, by the submission of a formal proposal to CEN. After consultation in CEN in 1998, CEN/TC 211, *Acoustics*, asked ISO/TC 43/SC 1, *Noise*, to prepare the ISO 17201 series.

Introduction

Shooting sound consists in general of three components: muzzle sound, impact sound and projectile sound. This part of ISO 17201 deals solely with projectile sound, which only occurs if the projectile moves with supersonic speed.

It specifies a method for calculating the source sound exposure level of projectile sound. It also gives guidelines for calculating the propagation of projectile sound as far as it deviates from the propagation of sound from other sources.

Projectile sound is described as originating from a certain point on the projectile trajectory, the “source point”. The sound source exposure level is calculated from the geometric properties and the speed of the projectile along the trajectory. As a result of non-linear effects, the frequency content of the projectile sound exposure depends on the distance from the source point. This is taken into account. Guidance is given on how the sound exposure level can be calculated from the sound exposure level at the receiver location, taking into account geometrical attenuation, attenuation due to the non-linear effects, and atmospheric absorption. In addition, the effects on the sound exposure level of the decrease of the projectile speed and of atmospheric turbulence are taken into account.

Projectile sound exposure levels are significant compared to the muzzle sound exposure level in a restricted region, the Mach region (region II — see Clause 4). Outside this region only diffracted or scattered projectile sound is received, with considerably lower levels than in the Mach region. Projectile sound behind the Mach region (region I) is negligible compared to muzzle sound. In this part of ISO 17201, a computational scheme for the levels in regions II and III is provided. In the bibliographical reference [2], measurements and calculations were compared for a set of calibres and distances, i.e. from the source point to the receiver location. For this set, there is a slight tendency of an overestimation of the projectile sound: on average 1,8 dB, A-weighted.

Acoustics — Noise from shooting ranges —

Part 4:
Prediction of projectile sound

1 Scope

This part of ISO 17201 provides a computational model 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 gives guidance on how to use this source level to calculate the sound exposure level at a receiver position.

This part of ISO 17201 is intended for calibres of less than 20 mm, but can also be applied for large calibres. Additionally, the data can be used to compare sound emission from different types of ammunition used with the same weapon. This part of ISO 17201 is meant for weapons used in civil shooting ranges, but is also applicable to military weapons.

The computational method can be used as a basis for environmental noise assessment studies. The prediction method applies to outdoor conditions, straight projectile trajectories, and streamlined projectile shapes. Because of the latter, it cannot be applied to pellets. Default values of parameters used in this part of ISO 17201 are given for a temperature of 10 °C, 80 % relative humidity, and a pressure of 1 013 hPa. Annex A can be used for calculations in other atmospheric conditions. Particularly for calibres < 20 mm, the 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 allow a more accurate result for air absorption to be obtained.

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 9613-2, *Acoustics — Attenuation of sound during propagation outdoors — Part 2: General method of calculation*

ISO 17201-1, *Acoustics — Noise from shooting ranges — Part 1: Determination of muzzle blast by measurement*

Guide to the expression of uncertainty in measurement (GUM). BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, first edition, 1993, corrected and reprinted in 1995.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 17201-1 and the following apply.

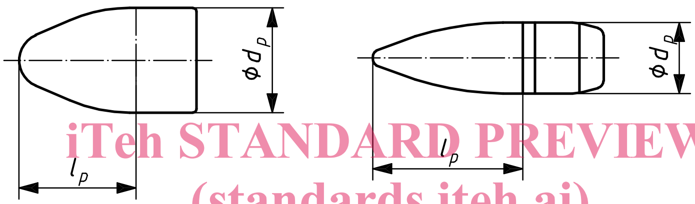
3.1
streamlined projectile
body of revolution of which the first derivative of the cross-sectional area $A(x)$ at a distance x behind the nose of the body is continuous for $0 \leqslant x < l_p$

NOTE For the definition of effective projectile length, l_p, see 3.2.

3.2
effective projectile length
l_p
distance between the nose and the cross-section with the maximum diameter of the projectile

See Figure 1.

NOTE The effective length of the projectile is measured along the length-axis of the projectile and is expressed in metres (m).



Key

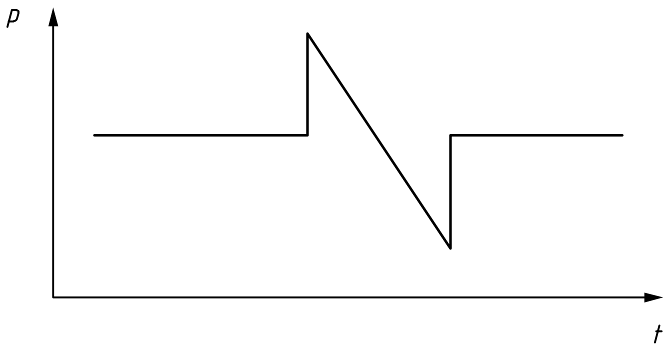
l_p effective projectile length (m)

d_p maximum diameter of projectile (m)

Figure 1 — Effective projectile length

3.3
N-wave
sound pressure having a 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 to the initial sound pressure

See Figure 2.



Key

t time

p sound pressure

Figure 2 — Assumed N-shaped waveform for sound of supersonic projectile at 1 m from source point on projectile's trajectory

3.4
duration time
T_c
time between two pressure increases of the N-wave

NOTE 1 The duration time is expressed in seconds (s).

NOTE 2 Resulting from the non-linear acoustic effects, T_c, for the N-wave along the sound path will change.

3.5
characteristic frequency
f_c
inverse of the duration time, T_c

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

NOTE The characteristic frequency is expressed in Hertz (Hz).

3.6
coordinate 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 The sound field of projectile sound is rotational symmetric around the line of fire.

NOTE 2 The co-ordinates are given in metres (m).

3.7
coherence distance
R_{coh}
distance between the source point on the trajectory and a receiver beyond which the contribution of different parts of the trajectory are incoherent due to atmospheric turbulence

NOTE The coherence distance is expressed in metres (m).

3.8
Mach number
M
ratio of projectile speed to local sound speed

3.9
source sound exposure level
$L_{E,s}$
sound exposure level expected at a distance of 1 m from the source point

NOTE 1 The source sound exposure level is expressed in decibels (dB).

NOTE 2 The reference distance of 1 m is “measured” in the direction of the receiver and not perpendicular to the trajectory.

3.10
source point
point where a line from the receiver perpendicular to the wave front intersects the projectile trajectory

NOTE In this part of ISO 17201, the source point is used to represent the trajectory that in principle is a line source [see Equation (4)].

3.11
projectile launch speed
v_{p0}
speed of the projectile at the muzzle

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

3.12
projectile speed
v_p
speed of the projectile along the trajectory

NOTE 1 The projectile speed is expressed in metres per second (m/s).

NOTE 2 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 could have to be taken into account.

3.13
end speed
v_{pe}
speed of the projectile as it hits the target or at the trajectory point where the Mach number is reduced to 1,01

NOTE The end speed is expressed in metres per second (m/s).

3.14
reference sound speed
adiabatic sound speed averaged over a period of at least 10 min

NOTE The reference sound speed is expressed in metres per second (m/s).

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 The fluctuating effective sound speed is expressed in metres per second (m/s).

3.16
standard deviation of the fluctuating acoustical index of refraction
μ_0
standard deviation of the ratio of the reference sound speed to the fluctuating effective sound speed

NOTE In accordance with [5], a value of $\mu_0^2 = 10^{-5}$ is used within the context of this part of ISO 17201 [see Equation (12)].

3.17
projectile speed change
κ
local change of projectile speed along the trajectory per length unit of trajectory

NOTE 1 The speed change is expressed in reciprocal seconds [(m/s · m) = 1/s].

NOTE 2 It is negative for non-self-propelled projectiles.

4 Regions

The wave front originating from the nose of the projectile has the shape of a cone (see Figure 3). The projectile speed decreases along the projectile trajectory. As a consequence, the wave front is curved. Three regions (I, II and III) are distinguished (see Figure 3). In regions I and III considerably lower sound exposure levels occur compared to those in region II. In this part of ISO 17201, 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 Equation (1):

$$v_{\mathrm{p}}(x) = v_{\mathrm{p0}} + \kappa\, x \tag{1}$$

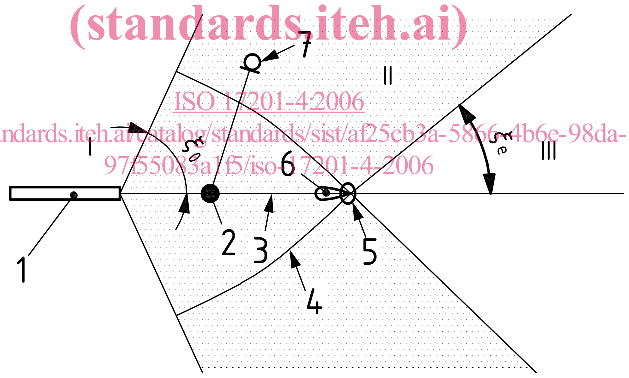
The boundaries of region II are described with the angles ξ_0 and ξ_{e}, shown in Figure 3. These angles are given by Equation (2):

$$\xi_0 = \arccos\left(\frac{c_{\mathrm{am}}}{v_{\mathrm{p0}}}\right) \quad \text{and} \quad \xi_{\mathrm{e}} = \arccos\left(\frac{c_{\mathrm{am}}}{v_{\mathrm{pe}}}\right) \tag{2}$$

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).



Key

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

Figure 3 — The three regions for describing the sound of a projectile

