BRITISH STANDARD

BS EN ISO 17201-1:2005

Incorporating corrigendum April 2009

Acoustics — Noise from shooting ranges —

Part 1: Determination of muzzle blast by measurement

ICS 95.020; 17.140.20; 97.220.10

BSI

British Standards

National foreword

This British Standard is the UK implementation of EN ISO 17201-1:2005. It is identical with ISO 17201-1:2005, incorporating corrigendum April 2009.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags. Text altered by ISO corrigendum April 2009 is indicated in the text by $\boxed{\text{AC}_1}$ $\langle\text{AC}_1|$.

The UK participation in its preparation was entrusted to Technical Committee EH/1/3, Acoustics — Residential and industrial noise.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Amendments/corrigenda issued since publication

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN ISO 17201-1

August 2005

ICS 95.020; 17.140.20; 97.220.10

English Version

Acoustics - Noise from shooting ranges - Part 1: Determination of muzzle blast by measurement (ISO 17201-1:2005)

Acoustique - Bruit des stands de tir - Partie 1: Mesurage de l'énergie sonore en sortie de bouche (ISO 17201-1:2005)

Akustik - Geräusche von Schießplätzen - Teil 1: Bestimmung des Mündungsknalls durch Messung (ISO 17201-1:2005)

This European Standard was approved by CEN on 31 July 2005.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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EN ISO 17201-1:2005

Foreword

This document (EN ISO 17201-1:2005) has been prepared by Technical Committee ISO/TC 43 "Acoustics" in collaboration with Technical Committee CEN/TC 211 "Acoustics", the secretariat of which is held by DS.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by February 2006, and conflicting national standards shall be withdrawn at the latest by February 2006.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Endorsement notice

The text of ISO 17201-1:2005 has been approved by CEN as EN ISO 17201-1:2005 without any modifications.

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Introduction

To obtain reliable data for the prediction of shooting sound levels at a reception point, the energy of sound emission produced by the muzzle blast is needed. The muzzle blast is produced by the propellant gas expelled from the barrel of a weapon; in most cases the gas has a supersonic fluid speed. Close to the muzzle, the sound pressure is very high and cannot be described with linear acoustics. For the purposes of this part of ISO 17201, the non-linear region is defined by the observation of a peak sound pressure level of 154 dB or more. This part of ISO 17201 defines how the sound source energy and directivity of the muzzle blast can be obtained from the measurement of sound exposure levels and how these measurements are to be carried out. The source energy, its directivity and spectral structure may be used as input for sound propagation models for environmental noise assessment. This cannot be used for calculations of sound exposure levels close to the weapon, for instance to estimate injury to people or animals.

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Acoustics — Noise from shooting ranges —

Part 1:
Determination of muzzle blast by measurement

1 Scope

This part of ISO 17201 specifies a method to determine the acoustic source energy of the muzzle blast for calibres of less than 20 mm or explosive charges of less than 50 g TNT equivalent. It is applicable at distances where peak pressures less than 1 kPa (equivalent to a peak sound pressure level of 154 dB) are observed. The source energy, directivity of the source and their spectral structure determined by this procedure can be used as input data to sound propagation programmes, enabling prediction of shooting noise in the neighbourhood of shooting ranges. Additionally, the data can be used to compare sound emission from different types of guns or different types of ammunition used with the same gun.

This part of ISO 17201 is applicable to guns used in civil shooting ranges but it can also be applied to military guns. It is not applicable to the assessment of hearing damage or sound levels in the non-linear region.

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 9613-1, *Acoustics — Attenuation of sound during propagation outdoors — Part 1: Calculation of the absorption of sound by the atmosphere*

IEC 60942:2003, *Electroacoustics — Sound calibrators*

IEC 61672-1:2002, *Electroacoustics — Sound level meters — Part 1: Specifications* [1]

3 Terms and definitions

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

3.1
instantaneous sound pressure
p
total instantaneous pressure at a point, in the presence of a sound wave, minus the atmospheric pressure at that point

NOTE   The instantaneous sound pressure is expressed in pascals.

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[1] Amalgamated revision of IEC 60651 and IEC 60804.

3.2
sound pressure level

L_p
ten times the logarithm to the base of 10 of the square of the ratio of a given root-mean-square sound pressure to the reference sound pressure

NOTE 1   The reference sound pressure is 20 µPa.

NOTE 2   The sound pressure level is expressed in decibels.

NOTE 3   The sound pressure level can be frequency weighted and time weighted.

3.3
peak sound pressure

p_{peak}
maximum absolute value of the instantaneous sound pressure during a stated time interval

NOTE   The peak sound pressure is expressed in pascals.

3.4
peak sound pressure level

L_{peak}
ten times the logarithm to the base of 10 of the square of the ratio of the peak sound pressure to the reference sound pressure of 20 µPa

NOTE   The peak sound pressure level is expressed in decibels.

3.5
event duration

T
stated time interval, long enough to encompass all significant sound of a stated event

NOTE   The event duration is expressed in seconds.

3.6
sound exposure

E
time integral of frequency-weighted squared instantaneous sound pressure

$$E = \int_T p^2(t)\, \mathrm{d}t \tag{1}$$

NOTE   The sound exposure is expressed in pascal-squared seconds (Pa²s).

3.7
sound exposure level

L_E
ten times the logarithm to the base 10 of the ratio of the sound exposure, E, to the reference sound exposure, E_0, the sound exposure being the time integral of the time-varying square of the frequency-weighted instantaneous sound pressure over a stated time interval, T, or an event

$$L_E = 10 \lg \left(\frac{E}{E_0} \right) \mathrm{dB} \tag{2}$$

NOTE E_0 is equal to the square of the reference sound pressure of 20 µPa multiplied by the time interval of 1 s (400 µPa²·1 s).

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3.8
source energy
Q
total sound source energy of the event

NOTE 1   The source energy is expressed in joules.

NOTE 2   The reference to 1 s yields the sound power L_W of a repeated event as defined in ⟨AC1⟩ ISO 3741 and
ISO 3745 ⟨AC1⟩ .

3.9
source energy level
L_Q
ten times the logarithm to the base 10 of the ratio of source energy, Q, to the reference source energy, Q_0

$$L_Q = 10 \lg \left(\frac{Q}{Q_0} \right) \text{dB}$$ (3)

where

Q_0 = 10^{-12} J

NOTE   The source energy level is expressed in decibels.

3.10
angular source energy distribution
$S_q(\alpha)$
acoustic energy radiated from the source into the far field, per unit solid angle

NOTE 1   The acoustic energy radiated by the source within a narrow cone centred on the direction α is

$$S_q(\alpha) = \frac{dQ}{d\Omega}$$ (4)

NOTE 2 Ω is the solid angle expressed in steradians.

NOTE 3   The angular source energy distribution $S_q(\alpha)$ is expressed in joules per steradian (J·sr^{-1}).

NOTE 4   Rotational symmetry is assumed around the line with α = 0.

3.11
interpolated angular source energy distribution
$\bar{S}_q(\alpha)$
continuous function in α of the source energy distribution $S_q(\alpha)$, derived by using a defined interpolation
method

NOTE   The interpolated angular source energy distribution, $\bar{S}_q(\alpha)$, is expressed in joules per steradian (J·sr^{-1}).

3.12
angular source energy distribution level
$L_q(\alpha)$
angular source energy distribution as a level relative to 10^{-12} J

$$L_q(\alpha) = 10 \lg \left(\frac{S_q(\alpha)}{S_{q_0}(\alpha)} \right) \text{dB}$$ (5)

where

$$S_{q_0}(\alpha) = 10^{-12} \ \text{J·sr}^{-1}$$

NOTE   The angular source energy distribution level, $L_q(\alpha)$, is expressed in decibels.

3.13
interpolated angular source energy distribution level
$\overline{L_q}(\alpha)$
continuous function in α of the angular source energy distribution level, $L_q(\alpha)$, derived by using a defined interpolation method

NOTE   The interpolated angular source energy distribution level is expressed in decibels.

3.14
angle alpha
α
angle between the line of fire and a line from the muzzle to the receiver (see Figure 3)

NOTE   The angle alpha is expressed in radians in all formulae.

3.15
angle beta
β
angle describing the rotation around the line of fire, anticlockwise from the view of the shooter, as the angle between the horizontal plane intersecting the muzzle from the right-hand side (see Figure 3)

NOTE   The angle beta is expressed in radians in all formulae.

3.16
angle gamma
γ
angle describing the inclination of the line of fire from the horizontal plane (see Figure 3)

NOTE   The angle gamma is expressed in radians in all formulae.

3.17
angle delta
δ
angle constituted by the projection of angle α on the horizontal plane (see Figure 3)

NOTE   The angle delta is expressed in radians in all formulae.

3.18
directivity
$D(\alpha)$
difference between the angular source energy distribution level of the source under test and the source energy distribution level of a monopole source with the same acoustic source energy

NOTE   The directivity is expressed in decibels.

3.19
muzzle distance
r_m
distance measured from the muzzle to the microphone point (see Figure 3)

NOTE   The distance is expressed in metres.

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4 Gun and ammunition

4.1 General

The information given in 4.2 to 4.6 is needed to unambiguously define the weapon plus ammunition combination for which the sound exposure level of the muzzle blast is estimated (items marked by an asterisk are mandatory). All terms have the meanings given in Reference [1] and Annex A.

4.2 Gun

The following features shall be stated:

— *description or brand name;

— *type of gun (shot gun, rifle, revolver, pistol, etc.);

— number, type and disposition of barrels (side-to-side, superposed, drilling, etc.);

— calibre;

— *barrel bore;

— *barrel length.

Figure 1 is a schematic view and gives the main terms used to describe the gun.
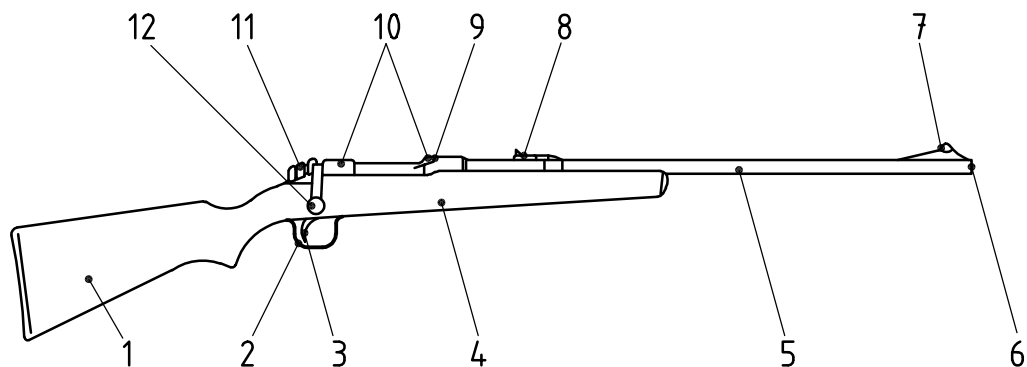
Key

1	stock	7	front sight
2	trigger guard	8	rear sight
3	trigger	9	bolt
4	magazine (inside)	10	receiver
5	barrel	11	safety lock
6	muzzle	12	bolt handle

Figure 1 — Main terms used to describe the gun (schematic view)

The main parts of smooth-bore barrel and a rifled barrel are given in Annex A.

Special features such as

— choke,

—   reload system,

—   *flame shield, and

—   *muzzle brake

should be mentioned.

4.3   Ammunition

The following information is needed:

—   *description or brand name;

—   *projectile calibre;

—   type and mass or chemical energy of propellant;

—   type of projectile (ball, pellets or blank);

—   *projectile mass.

In the case of shot guns:

—   total length of the cartridge;

—   type of tube;

—   type of wad;

—   *type, number, size and weight or type-number of pellets;

—   type of crimping.

Schematic views of bullet projectiles and shot gun cartridges are shown in Figure 2 with the names of their main components.

4.4   Ballistic parameters
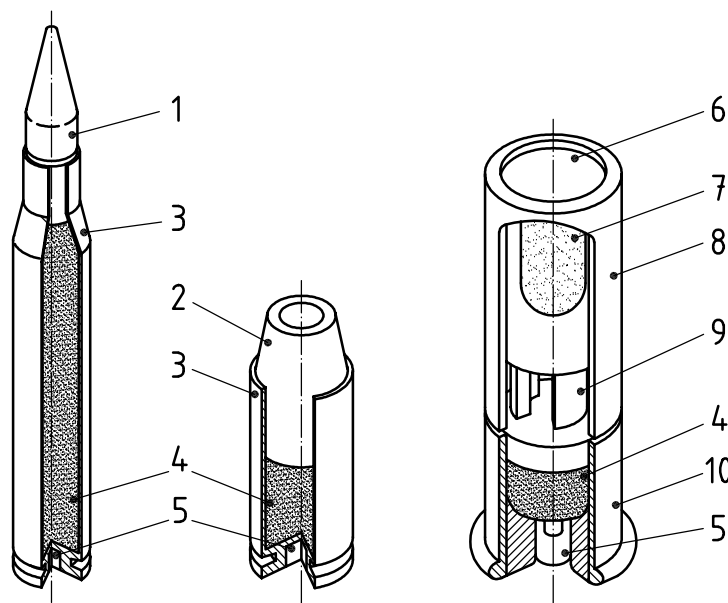
State parameters like

—   *muzzle speed (speed of the projectile close to the muzzle),

as result of a gun/ammunition combination as specified by the manufacturer.

NOTE   Muzzle speed is a calculated value that corresponds to the speed of the projectile itself for rifles, or to the speed of the centre of gravity of the cloud of pellets close to the muzzle of a shot gun.

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Key

1	projectile (bullet) for rifle	6	tube
2	projectile (bullet) for pistol	7	shot pellets
3	case	8	plastic cylinder
4	powder	9	wad
5	primer	10	case head

NOTE   The measurements can be influenced by conditions such as the heating of the barrel during repetitive shooting, the temperature, the humidity and the age of the ammunition.

Figure 2 — Schematic view of bullet projectiles and a shot gun cartridge

4.5   Test situation

Any object that can cause reflections or shield the muzzle blast shall be mentioned. Such objects can, for example, be a part of the weapon, the support of the weapon or part of this support. Also the gunman can be seen as a part of the weapon system that can shield the muzzle blast. All these elements, which are commonly used under normal operation of the weapon, shall be present during the measurement and should be mentioned in the report. Other circumstances which may affect the noise source data should also be reported. The gun shall be positioned as it would be under normal operating conditions. If the gun is put on a high support and fired with a rope, the shielding effect of the gunman is not taken into account. Therefore it should be ensured that the experimental set up is as close to normal operation conditions as possible (see also 7.2).

4.6   Other features

All other information concerning the test conditions or anything that may affect measured source data shall be reported.

EXAMPLES

⎯   the barrel in use in the case of a combination firearm, if the barrels have different features, especially bore,

⎯   special features, like silencers, muzzle brakes, etc., and

⎯   storage conditions of the ammunition (temperature, humidity, duration, etc.).

5 Basic concept for measurement and analysis

5.1 General

For the measurement of the muzzle blast, it is assumed that radiation of sound is rotationally symmetrical around the line of fire. This assumption is used to define spherical coordinates, r_m, α and β which are centred at the muzzle. The angles are defined in Clause 3 and are shown in Figure 3.

As the muzzle blast can be directional, measurements may be carried out in a circle. The goal is to measure the level and also the directivity pattern. An equal distance between measuring points makes it easier to use interpolation algorithms to get a continuous function for directivity pattern.

The measurements and the analyses shall yield spectral information in at least octave bands (preferably in one-third-octave-bands) from 31,5 Hz to 8 kHz.

The calculation method given in 5.2 to 5.6 applies to broadband analysis as well as octave-band or one-third-octave-band analysis.

5.2 Quantity to be measured

The basic quantity to be measured is the sound exposure level measured at a distance r_m and angles α and β:

$$L_E\left(r_m, \alpha, \beta\right) = 10 \lg \int_T \frac{p^2\left(r_m, t, \alpha, \beta\right)}{p_0^2 T_0} \, \mathrm{d}t \quad \mathrm{dB} \tag{6}$$

Assuming rotational symmetry, the sound exposure level is a function of r_m and α alone.

However, due to ground reflections when measuring above ground, the sound exposure level L_E will also depend on β. The corrections to remove ground reflections are described in 9.2. After the corrections, the sound exposure level is assumed to depend on the distance r_m and angle α only.
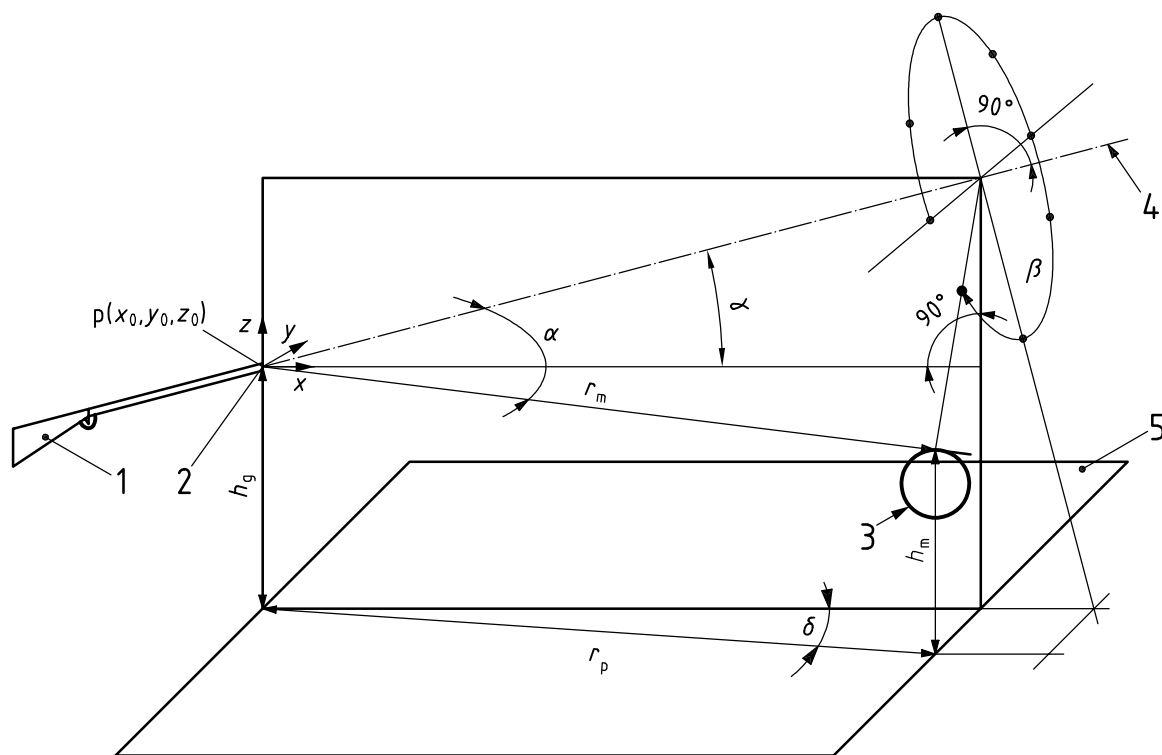
Key

1   gun

2   muzzle

3   microphone

4   line of fire

5   ground plane

NOTE   If the height of the microphone above ground is not the same as the height of the gun above ground, the angle α is not the same as the angle δ. The relation between these angles is given below for cases where the barrel is positioned horizontally:

$$\alpha = \arccos\left(\frac{r_p\cos(\delta)}{\sqrt{r_p^2 + (h_m - h_g)^2}}\right)$$

where

r_p is the projected distance on the ground plane from the muzzle to the microphone;

r_m is the distance from the muzzle to the microphone;

h_m is the height of the microphone above ground;

h_g is the height of the muzzle of the gun above ground.

Figure 3 — Angles α, β, γ and δ

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5.3 Angular source energy distribution level

The angular source energy distribution levels, $L_q(\alpha_n)$, are estimated on the basis of the sound exposure level measurements at N discrete angles α_n at the distance r_m by

$$L_q(\alpha_n) = L_E(r_m, \alpha_n) + A_{div}(r_m) - 11 \text{ dB} + A_{atm}(r_m) + A_z + A_{gr} \tag{7}$$

where

A_{div} is a correction that accounts for the geometric spread, $A_{div} = 10 \lg \left(\dfrac{r_m^2}{r_0^2} \right) \text{ dB} + 11 \text{ dB}$

and

r_0 = 1 m;

A_{atm} is a correction for air absorption (see ISO 9613-1);

A_{gr} is a correction in order to obtain free field conditions (see 9.2 and Reference [14]).

NOTE   This reference gives a simple algorithm to calculate the ground reflection of a spherical wave correctly, as described in Reference [16].

A_z is used to correct for non-standard meteorological conditions (see ISO 3741, ISO 3745 and ISO 9614-3).

$$A_z = -10 \lg \left(\frac{B}{B_0} \frac{T_0}{T} \right) \text{dB} \tag{8}$$

where

B is the air pressure under the conditions of measurement;

B_0 is the reference air pressure, B_0 = 1 013 hPa;

T is the temperature under the conditions of measurement;

T_0 is the reference temperature, T_0 = 296 K.

5.4   Interpolated angular source energy distribution level

In order to calculate the total source energy and to provide a continuous directivity function, a curve fitting for the angular source energy distribution level is needed. The curve-fitting methods used shall describe the periodic behaviour of the directivity function.

The angular source energy distribution level $\overline{L}_q(\alpha)$ is obtained by interpolation and shall be reported as follows:

$$\overline{L}_q(\alpha) = a_0 + \sum_{j=1}^{N-1} a_j \cos(j\,\alpha) \tag{9}$$

where N is the number of terms used to describe $\overline{L}_q(\alpha)$.

NOTE 1   This formulation corresponds to an approach according to Fourier without Sinus terms. As rotational symmetry is assumed the Sinus terms are zero.

NOTE 2   The parameters a_j may be obtained using Fourier Transformation, least-square fits, or any other interpolation method.

Equation (9) represents one interpolation method. Alternative interpolation procedures may be used when appropriate, see Annex B.

5.5   Source energy level

The source energy level is calculated from the interpolated angular source energy distribution levels by

$$L_Q = 10 \lg \frac{1}{r_0^2} \left(\int_{\beta=0}^{2\pi} \int_{\alpha=0}^{\pi} 10^{0,1\overline{L}q(\alpha)} \, r_0 \sin\alpha \, \mathrm{d}\beta \, \, r_0 \, \mathrm{d}\alpha \right) \mathrm{dB} \tag{10}$$

Since rotational symmetry is assumed, this may be written as

$$L_Q = 10 \lg 2\pi \left(\int_{\alpha=0}^{\pi} 10^{0,1\overline{L}q(\alpha)} \sin\alpha \, \mathrm{d}\alpha \right) \mathrm{dB} \tag{11}$$

5.6   Directivity

The directivity $D(\alpha)$ of the muzzle blast is given by

$$D(\alpha) = \overline{L}_q(\alpha) - \left(L_Q - 10 \lg 4\pi \, \mathrm{dB} \right) \tag{12}$$

6   Measurement site

6.1   Site

The measurement site shall be reasonably level, homogeneous with respect to the ground impedance, and free of objects that may cause reflections that affect the accuracy of the measurement.

EXAMPLE   Examples of homogeneous grounds are:

— concrete,

— water,

— asphalt,

— grass or sand.

6.2   Weather conditions

The average wind speed at 10 m height should be less than 3 m/s. The sky should be overcast.

The relative humidity should be less than 95 %. The background level of wind-induced sound at the microphone should not be so great that it interferes with the measured signal at any frequency of interest.

7 Measurement planning

7.1 General remarks

Apart from the muzzle blast, the event signal may also include projectile sound, reflections from objects and from the ground. When planning a measurement, it should be taken into consideration how these "unwanted" contributions can be separated from the muzzle blast in the later data analysis. Commonly used methods are the following.

a) **Window techniques**: This technique is applicable for signals that arrive at the microphone separated in time, where the width and position of the window is adjusted in such a way that only the sound from the muzzle blast can be analysed. It is typically used for reflecting objects and projectile sound. In a measurement layout with source and receiver heights that ensure a clear separation of the direct and the reflected wave from the ground, it may also be used to exclude the effect of ground reflections. In this case is $A_{gr} = 0$.

b) **Ground impedance models**: These models are used if the measured signal is a superposition of the direct wave and the reflected wave from the ground. They yield a prediction of the ground effect based on the reflection of a spherical wave at a complex impedance ground.

Other methods may also be used. The methods used shall be described.

7.2 Gun

The barrel should preferably be horizontal and at least 1,5 m above the ground. In some directions, the projectile sound wave and the muzzle blast can be separated by window techniques. For directions where this is not possible, the correction may be computed. Projectile sound is also generated by projectiles from shot guns and pistols as long as the speed of these projectiles is supersonic.

7.3 Measurement position

The measurement positions may be arranged in either a semicircle or a full circle. The angular increment of angle α should preferably be regular. The angular increment step should not exceed 45°. One measurement position should be close to the line of fire. Care shall be taken not to choose measurement angles too close to the border of the projectile sound region. The difference in the averaged broadband sound exposure level of the frequency range of interest between adjacent measuring points shall be smaller than 5 dB. In order to reduce meteorological effects, the distance between the source and measurement position should be chosen to be as short as possible.

The microphone should normally be placed at a distance of at least 10 m up to 50 m to ensure that the peak pressures do not exceed 1 kPa. It should be tested (considering the pressure limit of 1 kPa) at which distance this prerequisite is fulfilled. By increasing the measurement and source heights, the time delay between the direct and reflected signals can be increased.

7.4 Measurement equipment

Sound level meters and similar measurement instrumentation shall comply with the requirements for a type 1 instrument as specified in IEC 61672-1:2002.

Compliance with additional requirements for the measurement of impulsive noise is recommended. Such requirements are specified in IEC 61672-1.

If a digital or analog recording instrument is used for (intermediate) storage, it shall have an adequate bandwidth and dynamic range.

The measurement equipment, in particular the measurement microphones, shall be suitable for measurement of high peak sound pressures.

7.5 Dealing with projectile sound

Projectile sound occurs when the speed of a projectile is supersonic. This is typical for rifles, but can also be observed with shotguns and pistols. Projectile sound only takes place in a distinct region in front of the weapon (the Mach area). The border of the Mach area at the muzzle is defined by the angle ξ_0:

$$\xi_0 = \arccos\left(\frac{c}{v_0}\right) \tag{13}$$

where

v_0 is the projectile speed at the muzzle;

c is the speed of sound under the conditions of measurement.

For a measurement position where α equals ξ_0, the signals from the muzzle sound and the projectile sound arrive at the same time and cannot be separated by time windowing. For measurement angles with alpha smaller than ξ_0, the projectile sound always arrives first and may be separated by time windowing. Care shall be taken not to choose a measurement position too close to the border of the Mach area to enable the necessary time gap for a separation. In the case of noise from shotguns, the time delay between the projectile sound and muzzle blast can be so small that time windowing or other techniques cannot be applied. However, the projectile moves with supersonic speed for only a short distance and its sound may be considered as coming from a point source. Therefore the simultaneous inclusion of the projectile's sound with the muzzle blast is acceptable. An increase of delay between the two signals may be achieved by increasing the measurement distance for the measurement positions within the Mach area (for details, see ISO 17201-4).

8 Calibration and validation

System calibration shall include the response of all cables, amplifiers and accessories to be used when actual data are collected. Calibration shall be performed at appropriate times to ensure that the time-averaged sound pressure level can be measured over the entire dynamic range within the stated tolerance of the instrument. Acceptable acoustical calibration methods include the use of sound calibrators, acoustical shock sources, or static pressure devices. Electrical calibration means are acceptable for field use, provided that acoustical calibration is accomplished before and after field use. Electrical signals should be applied to the microphone input via a suitable adapter.

The complete measurement chain shall be calibrated by the user at regular intervals and at least before and after a series of measurements at at least one frequency. The sound calibrator shall fulfil the requirements for a class 1 sound calibrator as specified in IEC 60942:2003 under the actual environmental conditions.

The measurement instruments shall be checked regularly and shall be calibrated with traceability to a national standard.

For further guidance in calibrating for measurement of impulses, see ISO 10843.

9 Measurement procedures

9.1 General

At least five measurements of the sound exposure shall be made at each microphone position. The measured values of $E(\alpha,r_m)$ are averaged arithmetically (which means that the sound exposure levels are averaged energetically). It is preferable that simultaneous measurements be made at all microphone positions. Alternatively, measurements may be made sequentially but, as a minimum, two microphones should be used with one microphone always remaining at the same position.

If the peak sound pressure level exceeds 154 dB at any of the microphone positions, the measurement distance shall be increased. These peak sound pressures should preferably be read from the time/pressure signal, where the error due to limited high-frequency response of the equipment can be corrected.

9.2 Ground reflection correction

There are several methods to correct for the ground reflection. No corrections for ground reflection are necessary when windowing techniques are applied. Otherwise the resulting levels shall be corrected to free-field conditions by applications of another suitable method (see, for example, Annex B). This part of ISO 17201 requires that the method and the corrections be recorded. If a method other than $\boxed{\text{AC1}}$ the one described in Annex B $\boxed{\text{AC1}}$ is used to determine the ground reflection, the value of A_{gr} in Equation (7) shall be changed correspondingly.

10 Control of measurement layout

To determine whether or not the number of measurement points is sufficient, the following procedure may be applied.

Step 1: The source energy level $L_Q{}^{(1)}$ is calculated using the interpolated angular source energy distribution level as given in Equation (9):

$$L_Q{}^{(1)} = 10 \lg \left(2\pi \int_{\alpha=0}^{\pi} 10^{0,1\overline{L_q}(\alpha)} \sin\alpha \; d\alpha \right) \; \text{dB} \tag{14}$$

where the superscript 1 denotes this procedure.

Step 2: A source energy level $L_Q{}^{(2)}$ is calculated from the interpolated angular source energy distribution $\overline{S_q}(\alpha)$ as follows:

$$L_Q{}^{(2)} = 10 \lg \left(\frac{2\pi}{Q_0} \int_{\alpha=0}^{\pi} \overline{S_q}(\alpha) \sin\alpha \; d\alpha \right) \; \text{dB} \tag{15}$$

where

the superscript 2 denotes this procedure;

$\overline{S_q}(\alpha)$ is obtained with the same interpolation method used for the estimation of $\overline{L}_q(\alpha)$.

If the absolute value of the difference between $L_Q{}^{(1)}$ and $L_Q{}^{(2)}$ is 0,4 dB or less, the number of measured angular directions is considered to be sufficient:

$$\left| L_Q{}^{(1)} - L_Q{}^{(2)} \right| \leq 0,4 \; \text{dB} \tag{16}$$

11 Measurement uncertainty

11.1 General

The measurement uncertainties associated with the source energy level and the directivity determined in accordance with this part of ISO 17201 shall be evaluated, preferably in compliance with the GUM (*Guide to the Expression of Uncertainty in Measurement*)[6].

The uncertainties arise in part from variations between test sites, changes in atmospheric conditions, geometry of the environment, acoustical properties of the ground, background noise, and the type and calibration of the instrumentation. They are also due to variations in experimental techniques, including the number and location of microphone positions, sound source location and orientation, and determination of the corrections. In addition, uncertainties can occur if measurements are taken too close to the source; such uncertainties increase for smaller distances and lower frequencies.

The expanded measurement uncertainty together with the corresponding coverage factor shall be stated for a coverage probability of 95 % as defined in the GUM.

Guidance on how to express the uncertainty is given in Annex C.

11.2 Empirical part

This part of ISO 17201 provides two quantities to express the muzzle blast: the source energy level and its directivity. The contribution to the uncertainty from measurement as described above may be estimated from the variance $s_D{}^2$ of the directivity:

$$s_D{}^2 = \frac{1}{n \cdot m - N} \sum_{i=1}^{n} \sum_{j=1}^{m} \left[\overline{L}_q(\alpha_i) - L_{q,j}(\alpha_i) \right]^2 \tag{17}$$

where

m is the number of repetitive measurements;

n is the number of measured directions;

$L_{q,j}(\alpha_i)$ is the measured angular source energy distribution level j, in direction α_i;

N is the number of coefficients used in Equation (9) (see 5.4).

The uncertainty contribution, Δ_D, of the directivity is given by

$$\Delta_D = \frac{s_D \cdot t \;\; (n \cdot m - N, P)}{\sqrt{m}} \tag{18}$$

where

t is Student's factor;

p is the coverage probability (chosen to be 0,05).

Table 1 — Distribution of *t*-values in consideration of the number of degrees of freedom

Number of degrees of freedom	Coverage probability, P %	
	68,27	95
1	1,84	12,71
5	1,11	2,57
10	1,05	2,23
20	1,03	2,09
40	1,01	2,02
NOTE Taken from Reference [6].		

For the source energy level, the equivalent uncertainty contribution is given by

$$\Delta_Q = \frac{s_D \cdot t \ (n \cdot m - 1, P)}{\sqrt{n \cdot m - 1}} \qquad (19)$$

The uncertainty contributions given in Equations (18) and (19) cover those of the measurement method used. They shall be supplemented by the uncertainty contribution resulting from the measurement of the sound exposure level $L_E(r,\alpha)$ and the other quantities given in Equation (7), as expressed in Annex C.

An example is given in Annex B.

12 Report

The report shall document the primary data recorded (at least octave-band sound exposure and the peak sound pressure level of each shot) and reported, together with a description of the measurement and analysis conditions including measurement uncertainty (see Clause 11).

All measurement quantities shall be given in SI units.

The height of the microphone above the ground or relating to the sound source shall be stated.

The way in which the sound from supersonic projectiles and ground reflection have been eliminated, how the octave-band analysis has been performed, and which corrections were used shall be described. At least one example of the time/pressure signal for one measurement position shall be shown. The directivity patterns are given by listing the interpolation coefficient of Equation (9) for each frequency band.

All measurement equipment shall be specified, together with the date and result of the last traceable calibration. The guns and the ammunition shall be specified, as well as the meteorological conditions (wind speed, temperature, humidity, air pressure and cloud cover).

Annex A
(informative)

Small arms glossary

A.1 Terms and definitions

A.1.1
action
combined parts of a firearm that determine how a firearm is loaded, discharged and unloaded

NOTE   Most handguns are referred to as "single-action" or "double-action." A single-action firearm requires the user to manually pull back the hammer before the firearm can be discharged (like the old western revolvers). A double-action firearm allows the user to either manually cock the hammer or simply pull the trigger and allow the firearm to cock and release the hammer on its own.

A.1.2
automatic action
firearm that loads, fires and ejects cartridges as long as the trigger is depressed and there are cartridges available in the feeding system (i.e. magazine or other such mechanism)

NOTE   Automatic action firearms are machine guns. [2]

A.1.3
bolt action
firearm, typically a rifle, that is manually loaded, cocked and unloaded by pulling a bolt mechanism up and back to eject a spent cartridge and load another

NOTE   Bolt-action firearms are popular for hunting, target shooting, and biathlon events. A bolt-action rifle allows the shooter maximum accuracy, but may be too slow or cumbersome for some shooting sports.

A.1.4
locked breech action
any action wherein the breech bolt is locked to the barrel or receiver, through a portion or all of the recoiling motion

A.1.5
semi-automatic action
firearm in which each pull of the trigger results in a complete firing cycle, from discharge through reloading

NOTE 1   It is necessary that the trigger be released and pulled for each cycle. These firearms are also called "autoloaders" or "self-loaders." The discharge and chambering of a round is blow-back operated, recoil operated, or gas operated.

NOTE 2   An automatic action firearm loads, discharges, and reloads as long as ammunition is available and the trigger is depressed. A semi-automatic firearm only discharges one cartridge with each squeeze of the trigger.

A.1.6
pump action
firearm that features a movable forearm that is manually actuated to chamber a round, eject the casing, and put another round in position to fire

---

2) Since 1934, it has been unlawful in the US to sell or possess an automatic firearm without special permission and licensing from the US Department of the Treasury, in addition to other measures.

A.1.7
black powder firearms
see muzzle loaders (A.1.26)

A.1.8
bolt action
see bolt (A.1.3)

A.1.9
bore diameter
⟨rifled barrels⟩ minor interior diameter of a barrel which is the diameter of a circle formed by the tops of the lands in a rifled barrel

⟨shotguns⟩ interior dimension of the barrel forward of the chamber but before the choke

A.1.10
breech face
that part of the breech block which is against the head of the cartridge case or shot shell during feeding and firing

NOTE   Sometimes called breech block face.

A.1.11
calibre
term used to designate the specific cartridges for which a firearm is chambered

NOTE   It is the approximate diameter of the circle formed by the tops of the lands of a rifled barrel. It is the numerical term included in the cartridge name to indicate a rough approximation of the projectile diameter (i.e. 30 calibre).

A.1.12
carbine
rifle of short length and light mass, originally designed for horse-mounted troops

A.1.13
chamber
⟨rifle, shotgun or pistol⟩ part of the barrel bore that has been formed to accept a specific cartridge or shell

⟨revolver⟩ holes in the cylinder that have been formed to accept a specific cartridge

A.1.14
choke
interior constriction at or near the muzzle end of a shotgun barrel for the purpose of controlling shot dispersion

A.1.15
choke margin
that portion of the choke forward of the greater constriction (see Table A.1)

Table A.1 — Choke margins in Europe and United States

	Choke markings, European	Choke markings, United States
Full choke	*	FC, Full (greatest constriction)
Improved-modified	**	Imp. Mod. (less constriction)
Modified	***	Mod. (less constriction)
Improved cylinder	****	IC, Imp. Cyl. (less constriction)
Cylinder	CL	
Skeet		Skeet, Sk (less constriction)
Cylinder bore		Cyl. (least constriction)
NOTE Some firearm manufacturers in the United States also use the European system.		

EN ISO 17201-1:2005

A.1.16
compensator
device attached to the muzzle end of the barrel that utilizes propelling gases to reduce recoil or noise or both

See also muzzle brake (A.1.25).

A.1.17
cone, forcing
tapered lead from the shotgun chamber diameter to the bore diameter, tapered lead from the bore diameter to the choke diameter, or tapered lead entrance to the bore in the rear of a revolver barrel

A.1.18
firearm
assembly of a barrel and action from which a projectile is propelled as a result of combustion

A.1.19
gauge
term relating to the number of bore diameter lead balls weighing 1 lb

NOTE   It is a term used to identify most shot gun bores, with the exception of the 410 shot gun.

A.1.20
groove diameter
major diameter in a barrel which is the diameter of a circle circumscripted by the bottom of the grooves in a rifled barrel

A.1.21
grooves
see rifling (A.1.33)

A.1.22
handgun
firearm designed to be held and fired with one hand

A.1.23
headspace
distance from the face of the closed breech of a firearm to the surface in the chamber on which the cartridge seats

A.1.24
machine gun
see automatic action (A.1.2)

A.1.25
muzzle-brake
device at the muzzle end, usually integral with the barrel, that uses the emerging gas behind a projectile to reduce recoil

See also compensator (A.1.16).

A.1.26
muzzle loader
any firearm loaded through the muzzle

NOTE   Also called "black powder" firearms. They may be antique, replica or of modern design.

A.1.27
over and under
firearm with two barrels, one above the other

A.1.28
pistol
handgun in which the chamber is part of the barrel

A.1.29
automatic pistol
common but improperly used term to describe semi-automatic pistols

NOTE   See semi-automatic action for a description of how these pistols operate.

A.1.30
pump gun
See pump action (A.1.6).

A.1.31
revolver
firearm, usually a handgun, with a cylinder having several chambers so arranged as to rotate around an axis and be discharged successively by the same firing mechanism

A.1.32
rifle
firearm having spiral grooves in the bore and designed to be fired from the shoulder

A.1.33
rifling
grooves formed in the bore of firearm barrel to impart rotary motion to a projectile

A.1.34
semi-automatic
firearm which fires, extracts, ejects and reloads only once for each pull and release of the trigger

A.1.35
shot gun
smooth bore shoulder firearm designed to fire shells containing numerous pellets or a single slug

A.1.36
twist
distance required for one complete turn of rifling, usually expressed as a ratio

A.2 Examples of firearms
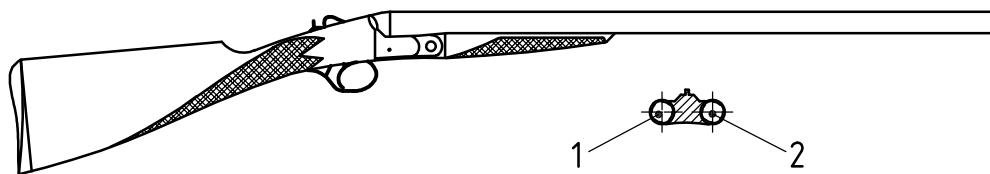
A.2.1   Smooth-bore barrelled firearms

Figure A.1 — Single-shot shotgun
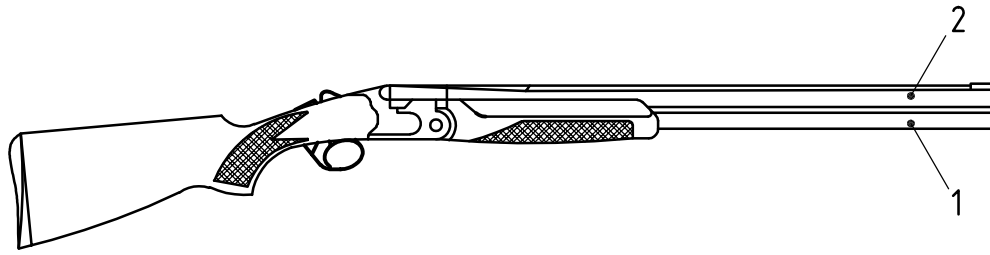
Key
1 top barrel
2 bottom barrel

Figure A.2 — Over-and-under shotgun

Key
1 right barrel
2 left barrel

Figure A.3 — Side-by-side shotgun

Figure A.4 — Pump gun

Figure A.5 — Semi-automatic shotgun (locked breech action)

A.2.2   Combination smooth-bore and rifled barrelled firearms

Key
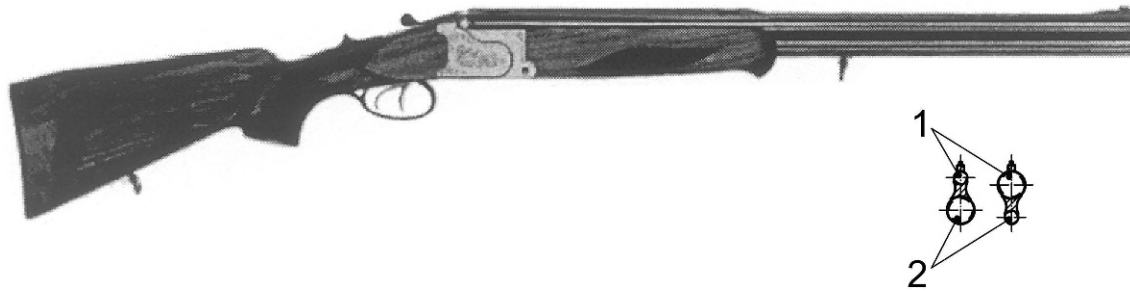
1   top barrel
2   bottom barrel

Figure A.6 — Over-and-under combination
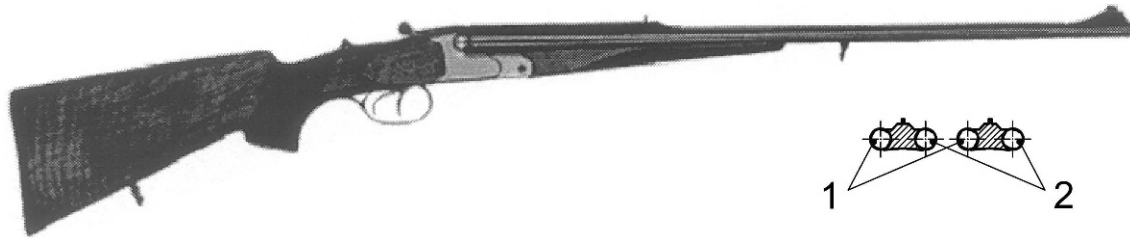
Key

1   left barrel
2   right barrel

Figure A.7 — Side-by-side combination
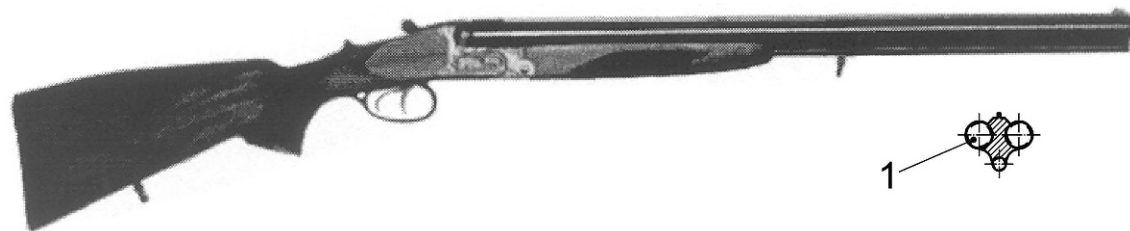
Key

1   two rifled barrels and one smooth-bore barrel, or two smooth-bore barrels and one rifled barrel

Figure A.8 — Drilling/three-barrelled gun

BS EN ISO 17201-1:2005
EN ISO 17201-1:2005

A.2.3   Rifled barrelled firearms

Figure A.9 — Single-shot rifle
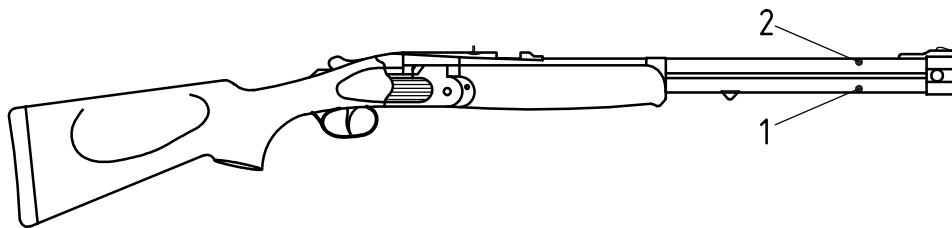
Key
1   top barrel
2   bottom barrel

Figure A.10 — Express double rifle

Figure A.11 — Semi-automatic rifle with locked breech action

Figure A.12 — Semi-automatic rifle with blow-back action

Figure A.13 — Bolt-action rifle

Figure A.14 — Submachine gun with blow-back action

Figure A.15 — Assault rifle (automatic rifle with locked breech action)

Figure A.16 — Machine gun with locked breech action

A.2.4 Pistols and revolvers
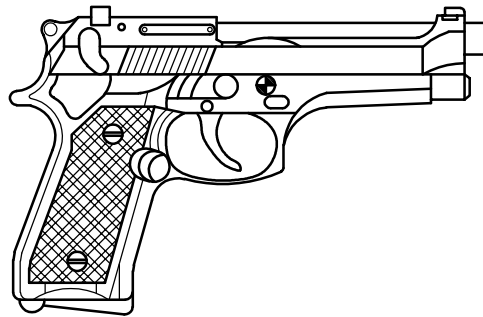
Figure A.17 — Semi-automatic pistol with locked breech action
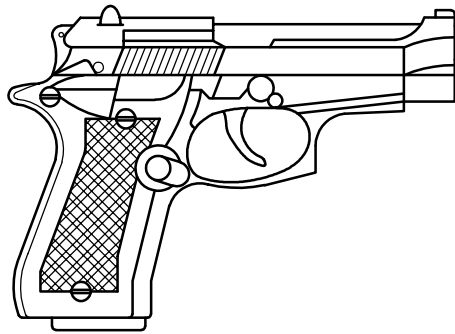
Figure A.18 — Semi-automatic pistol with blow-back action

Figure A.19 — Single-action revolver
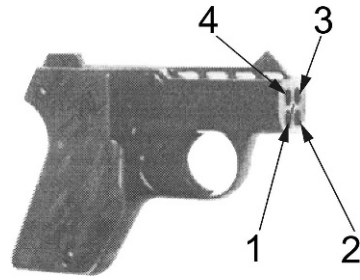
Key

1 bottom right barrel
2 bottom left barrel
3 top left barrel
4 top right barrel

Figure A.20 — Multi-barrel handgun

Figure A.21 — Double-action revolver

A.2.5 Black-powder firearms

Figure A.22 — Muzzle-loading rifle

Figure A.23 — Muzzle-loading pistol

Figure A.24 — Muzzle-loading revolver

A.3 Barrels

A.3.1 Smooth-bore barrel

Key
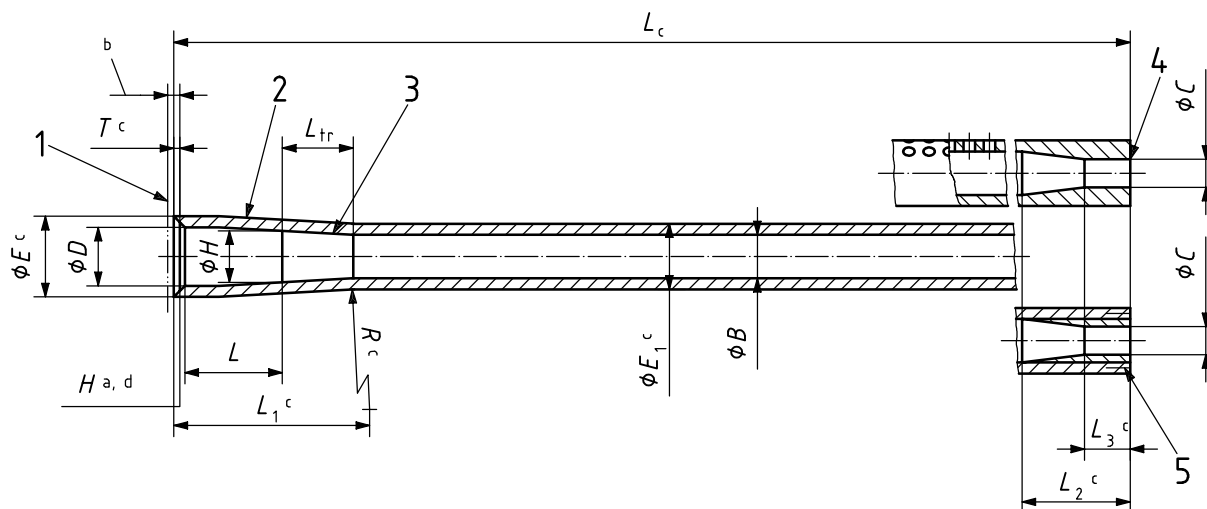
1 breech (block) face
2 chamber
3 forcing cone
4 choke
5 mobile choke

a Basic.

b Headspace dimension.

c Manufacturer's dimension.

ID	Definitions	Notes
D	1st chamber diameter	
H	2nd chamber diameter	
L	Chamber length	
B	Bore diameter	
C	Choke diameter	$C = B$ – constriction value
L_c	Barrel length	
E, E_1	External diameter	

Figure A.25 — Smooth-bore barrel

A.3.2   Rifled barrel

Key
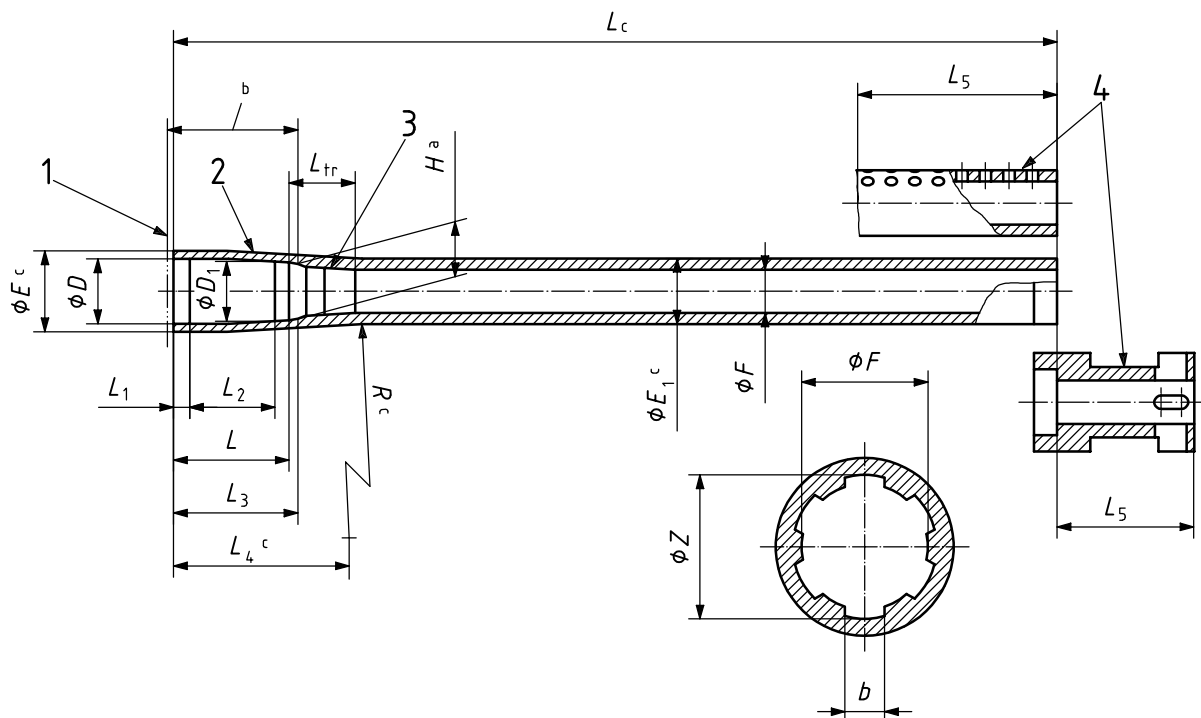
1   breech (block) face

2   chamber

3   chamber lead

4   muzzle brake or flash hider or any muzzle device

a   Basic.

b   Headspace dimension.

c   Manufacturer's dimension.

ID	Definitions
D	1st chamber diameter
D_1	2nd chamber diameter
L	Chamber length
L_1	Distance of D from barrel rear end face
L_2	Distance between chamber diameters (D, D_1)
H	Basic shoulder diameter
L_3	Distance of H from barrel rear end face
L_{tr}	Chamber lead length
F	Bore diameter
Z	Groove diameter
b	Groove width
	Number of grooves
	Twist
	Groove area
L_c	Barrel length
E, E_1	External diameter

Figure A.26 — Rifled barrel

Annex B
(informative)

Example

B.1 Measurement positions

The muzzle blast of a shotgun using a 0,67 m full-choked barrel and a charge of 24 g of lead pellets was measured. The gun was mounted on a vice in such a way that the muzzle was positioned within 1,5 m $\pm$ 0,03 m above ground. The ¼ inch microphones were positioned on a semicircle at a distance of 10 m, at a height of 1,5 m above ground, using a microphone orientation for grazing incidence. The ammunition was manufactured in such a way that the average pellet speed at the muzzle was 400 m/s. The ammunition was stored under standard conditions in an air-conditioned container. The angle of the line of fire with the ground was equal to zero.

The angular increment was chosen to be 30°. The zero position was chosen to lie at 0,025 m to the perpendicular line of fire. The distance of all positions was checked using blanks from a revolver. The microphone position was adapted until the muzzle blast signal of the blank showed the same time delay as the signal for the zero position. Additionally, the 15° position was measured.

B.2 Measured data

The data given in Table B.1 were obtained from the measured sound pressure using Fourier transform to obtain the following frequency bands.

Table B.1 — Measured angular sound exposure level in decibels

Angle degrees	31,5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 000 Hz	2 000 Hz	4 000 Hz	8 000 Hz
0	90,6	96,9	98,2	107,9	112,5	112,5	113,8	112,4	109,7
0	88,0	95,3	94,9	108,5	112,3	113,7	111,7	110,3	107,9
0	87,9	96,7	101,0	103,8	111,3	112,8	114,2	111,7	108,3
0	89,2	97,8	100,3	107,2	113,2	114,3	111,8	112,6	107,8
0	88,1	97,8	101,9	104,0	111,7	114,1	111,9	109,7	106,0
15	87,6	96,4	102,1	99,3	105,7	111,3	106,3	105,0	103,8
15	86,4	95,6	101,5	97,9	106,2	110,6	108,5	106,0	103,9
15	86,5	95,7	102,3	101,3	105,8	109,4	107,6	103,9	102,9
15	87,1	96,5	102,2	99,9	105,3	112,8	107,7	104,7	104,4
15	87,0	96,0	102,2	100,7	104,2	109,3	106,4	105,3	101,4
30	85,0	93,9	101,1	101,1	108,6	108,2	105,1	99,4	97,2
30	84,9	93,7	100,9	101,0	109,4	106,7	102,9	99,3	95,2
30	84,9	94,0	101,1	101,2	109,0	108,3	104,8	100,9	97,6
30	84,8	94,1	101,2	100,9	108,9	108,4	102,9	102,0	100,3
30	85,4	94,0	101,0	100,6	108,3	108,9	103,5	101,0	94,5
60	78,5	88,3	95,8	95,4	98,6	100,3	99,3	98,5	94,7
60	78,8	87,8	95,5	95,2	98,4	99,7	98,8	96,2	94,0
60	79,4	88,2	95,5	95,4	99,4	98,6	100,5	97,5	93,1
60	78,8	87,7	95,4	95,0	99,5	98,9	98,7	96,5	94,2
60	78,9	88,4	95,5	94,9	98,9	98,7	99,3	98,1	95,2
90	72,9	83,3	89,9	88,2	96,9	96,2	95,9	93,3	90,5
90	74,1	82,9	90,1	88,3	96,6	96,5	94,0	93,2	89,7
90	72,9	83,5	90,1	87,9	96,6	96,2	94,6	91,5	91,0
90	73,3	83,8	90,5	88,3	97,2	96,9	95,8	92,3	90,6
90	73,0	83,6	90,1	88,1	96,3	95,7	93,7	91,3	90,8
120	68,9	78,6	85,1	83,7	92,3	92,1	91,3	91,5	89,4
120	69,1	79,5	85,5	84,1	91,9	92,8	91,7	91,1	89,0
120	70,7	79,7	85,3	84,0	92,0	92,4	92,4	92,1	89,8
120	71,2	80,1	85,5	84,1	92,0	91,6	89,2	92,1	89,2
120	71,3	80,0	85,3	83,8	91,8	93,2	92,7	92,7	89,1
150	64,9	75,1	82,1	84,0	88,7	87,5	86,9	82,6	78,2
150	67,9	77,0	82,4	83,9	88,2	87,8	87,5	85,6	80,0
150	67,5	76,8	82,0	83,4	86,3	87,8	89,5	87,0	87,0
150	67,3	77,6	82,9	84,0	88,4	87,7	87,1	84,3	81,2
150	65,9	77,0	82,5	84,0	87,8	88,4	87,8	87,6	85,0
180	63,3	74,5	80,8	79,5	90,6	90,5	91,5	86,5	86,3
180	63,8	74,0	80,7	81,0	88,2	90,8	89,5	86,3	84,6
180	64,5	74,3	81,1	81,5	87,4	88,4	89,7	84,7	82,9
180	64,4	75,8	81,3	81,1	89,5	91,5	89,3	89,6	86,2
180	63,0	74,6	81,4	81,8	88,0	90,0	90,8	88,4	85,0

B.3 Removal of projectile sound

The sound pressures at 0°, 15° and 60° are depicted in Figure B.1. The time shift is smaller than 2 ms between the two signals. Gating does not work. Therefore no correction was taken.
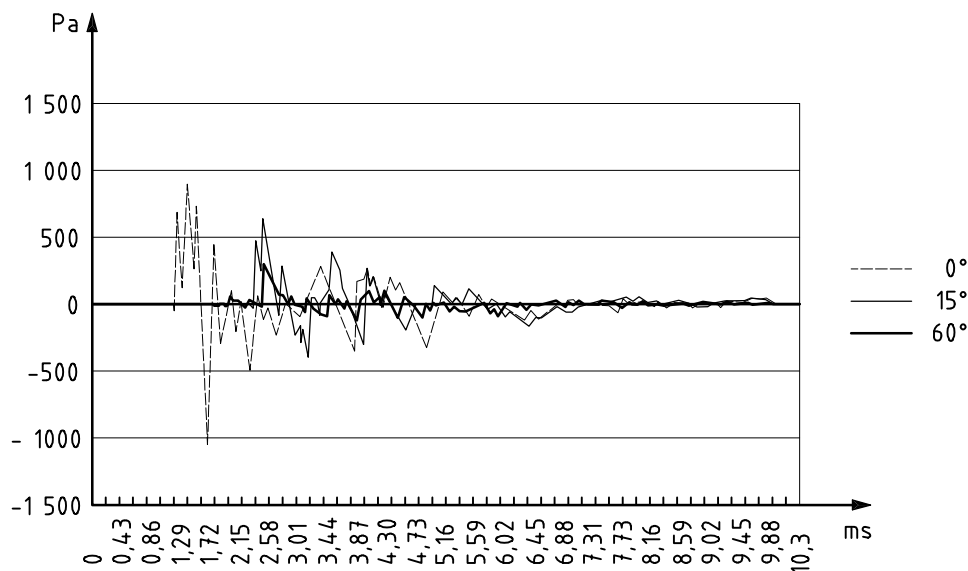
Figure B.1 — Measured sound pressure at 0°, 15° and 60° for 0,67 m chocked barrel,
24 g pellets and muzzle speed 400 m/s

B.4 Removal of ground reflection

The ground effect was corrected by the values given in Table B.2, derived from the measured impedance at the site after the measurements were performed. The interference minimum was measured. Varying the flow resistance and the penetration depth in a sound propagation model, based on Reference [14], the ground impedance was obtained.

Table B.2 — Correction for ground reflection

Frequency, Hz	31,5	63	125	250	500	1 000	2 000	4 000	8 000
Ground reflection, dB	−5,2	−5,2	−3,4	2,7	−1,5	−1,5	−1,1	0,9	0,6
NOTE According to Reference [14].									

B.5 Corrected measurement data

The measured data were averaged and corrected for the ground reflection (see Table B.3).

Table B.3 — Averaged levels after removal of ground reflection

Values in decibels

| Direction angle degrees	Average levels	31,5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 000 Hz	2 000 Hz	4 000 Hz	8 000 Hz
0	118,0	83,7	91,8	96,5	109,4	110,8	112,0	111,7	110,6	108,7
15	112,9	81,6	90,8	98,8	102,4	103,8	109,2	105,9	103,6	103,5
30	110,7	79,7	88,6	97,5	103,8	107,5	106,4	102,7	99,6	97,8
60	104,1	73,5	82,7	92,0	97,6	97,2	97,6	98,1	96,4	94,8
90	100,3	67,9	78,1	86,6	90,7	95,2	94,8	93,7	91,4	91,1
120	97,5	65,1	74,3	81,8	86,6	90,3	90,8	90,4	90,9	89,8
150	92,9	61,5	71,5	78,9	86,5	86,4	86,4	86,8	84,8	84,0
180	94,8	58,7	69,5	77,7	83,8	87,4	88,8	89,1	86,5	85,7

B.6 Directivity and source energy

Using the measured data of Table B.2, a cubic spline procedure was used to interpolate between the different directions.

Figures B.2 and B.3 illustrate the angular source energy level and the directivity.

The difference between the two interpolation methods is less than 0,4 dB according to Clause 10. However, the interpolation form is slightly different as can be seen.
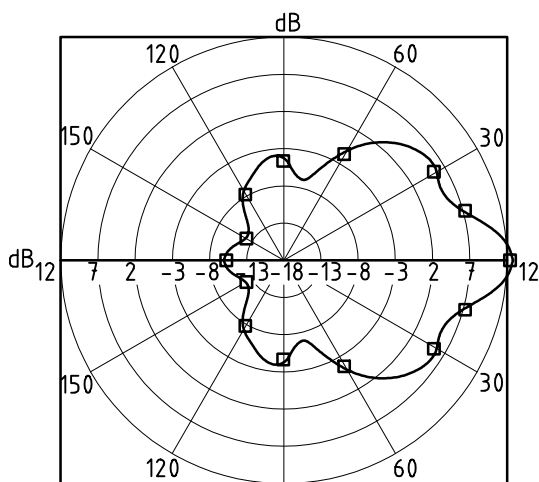
NOTE 1   The measured values are denoted by squares.

NOTE 2   Results depicted are obtained by the cosine transform of the interpolated angular source energy distribution.

Figure B.2 — Directivity $D(\alpha)$ of A-weighted angular source energy level using cubic spline interpolation as described by Equation (15)

Table B.4 — Results

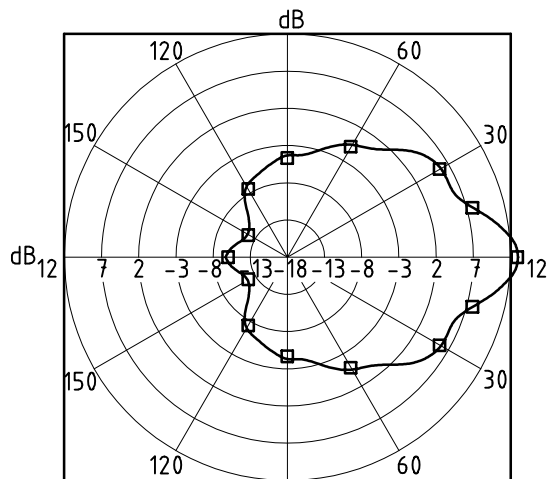| A-weighted source energy level L_Q = 135,8 dB			
Angle degrees	$D(\alpha)$ dB	Index j	Coefficient dB
0	13,2	0	−2,99
15	8,1	1	9,74
30	5,8	2	2,03
45	2,7	3	1,24
60	−0,7	4	0,99
75	−3,0	5	-0,36
90	−4,5	6	0,69
105	−5,6	7	0,21
120	−7,3	8	0,39
135	−10,2	9	0,42
150	−11,9	10	0,33
165	−10,9	11	0,35
180	−10,0	12	0,33

NOTE 1   The measured values are denoted by squares.

NOTE 2   Results depicted are obtained by the cosine transform of the interpolated angular source energy distribution level.

Figure B.3 — Directivity $D(\alpha)$ of the A-weighted angular source energy level using cubic spline interpolation as described by Equation (14)

Table B.5 — Results

A-weighted source energy level L_Q = 136,1 dB			
Angle	$D(\alpha)$	Index j	Coefficient
degrees	dB		dB
0	12,9	0	−3,32
15	7,6	1	9,77
30	5,7	2	2,34
45	4,4	3	1,43
60	−1,4	4	0,64
75	−6,4	5	−1,40
90	−4,6	6	0,55
105	−4,8	7	1,17
120	−7,7	8	0,85
135	−11,0	9	0,32
150	−12,2	10	0,06
165	−10,9	11	0,31
180	−10,3	12	0,39
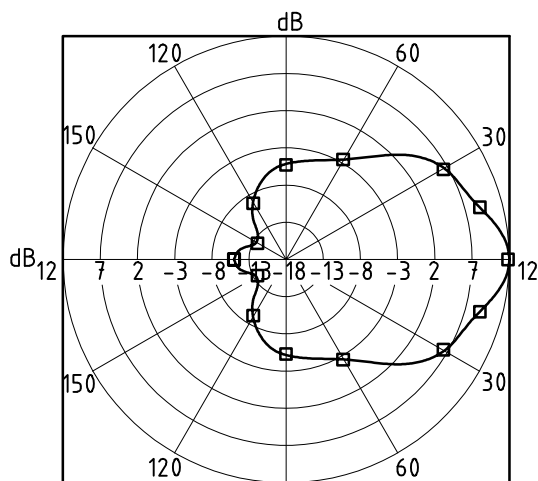
NOTE 1   The measured values are denoted by squares.

NOTE 2   Results are obtained by the cosine transform of the interpolated angular source energy level at 1 kHz.

Figure B.4 — Directivity $D(\alpha)$ of angular source energy distribution level for the 1 kHz octave band using cubic spline interpolation as described by Equation (15)

Table B.6 — Results

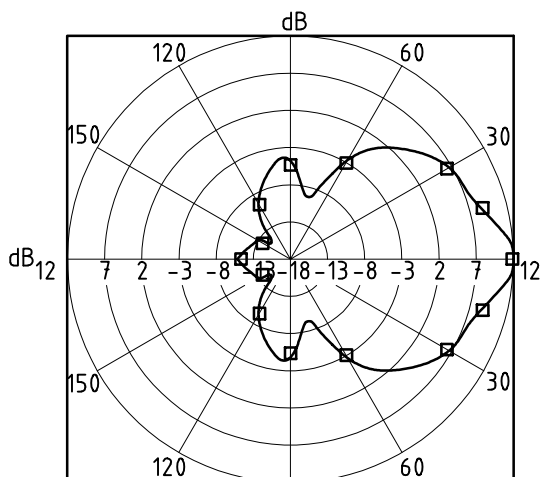| A-weighted source energy level L_Q = 130,8 dB			
Angle	$D(\alpha)$	Index j	Coefficient
degrees	dB		dB
0	12,2	0	−3,87
15	9,3	1	10,61
30	6,6	2	2,49
45	2,1	3	1,36
60	−2,3	4	1,31
75	−4,2	5	−0,76
90	−5,1	6	0,20
105	−6,6	7	−0,03
120	−9,1	8	0,23
135	−12,1	9	0,24
150	−13,5	10	0,15
165	−12,1	11	0,19
180	−11,0	12	0,13

NOTE 1   The measured values are denoted by squares.

NOTE 2   Results are obtained by the cosine transform of the interpolated angular source energy at 1 kHz.

Figure B.5 — Directivity $D(\alpha)$ of angular source energy distribution level for the 1 kHz octave band using cubic spline interpolation as described by Equation (14)

Table B.7 — Results

A-weighted source energy level L_Q = 131,1 dB			
Angle degrees	$D(\alpha)$ dB	**Index j**	**Coefficient** dB
0	12,0	0	−4,28
15	9,1	1	11,62
30	6,5	2	3,05
45	3,5	3	1,66
60	−2,8	4	1,08
75	−8,9	5	−2,07
90	−5,1	6	0,06
105	−5,6	7	1,24
120	−9,4	8	0,57
135	−13,7	9	0,02
150	−13,6	10	−0,36
165	−11,8	11	0,13
180	−11,2	12	0,58

B.7 Presentation of the result

In Table B.8, the results are given for the A-weighted levels and octave band levels. The first line contains the total A-weighted energy level and the following lines the octave bands. The third column obtains the angular source energy distribution level for $j = 0$ of the cosine transform [see Equation (9)]. The other lines contain the higher order cosine coefficients. Table B.8 lists the coefficients of the cosine transfer for the angular source energy distribution levels over the frequency. Column 2 gives the source energy levels.

Table B.8 — Source energy levels, L_Q, **and coefficients,** α_j, **of the angular source energy distribution levels**, $L_q(\alpha)$

Cosine coeffic.	Source energy level dB	α_j												
		0 dB	**1** dB	**2** dB	**3** dB	**4** dB	**5** dB	**6** dB	**7** dB	**8** dB	**9** dB	**10** dB	**11** dB	**12** dB
A-level	135,8	121,8	9,7	2,0	1,2	1,0	−0,4	0,7	0,2	0,4	0,4	0,3	0,4	0,3
31,5 Hz	104,4	89,7	10,7	1,4	1,2	−0,4	0,2	0,1	0,2	0,1	0,1	0,1	0,1	0,1
63 Hz	113,6	99,3	10,0	1,3	0,9	0,04	0,1	−0,1	0,04	0,03	0,02	0,03	0,0	0,02
125 Hz	122,2	107,4	10,4	0,8	−0,01	−0,2	−0,3	−0,4	−0,3	−0,2	−0,2	−0,2	−0,2	−0,2
250 Hz	128,3	113,3	10,5	2,3	−0,1	−0,7	0,4	−0,03	0,7	0,8	0,7	0,7	0,6	0,7
500 Hz	130,8	115,6	10,3	1,5	0,7	0,2	−1,4	-0,4	0,4	0,9	1,0	0,9	0,8	0,8
1 kHz	130,8	116,0	10,6	2,5	1,4	1,3	−0,8	0,2	−0,03	0,3	0,2	0,2	0,2	0,1
2 kHz	128,8	115,2	9,3	2,1	0,8	1,3	0,07	1,0	0,4	0,4	0,4	0,3	0,3	0,3
4 kHz	126,7	113,5	8,8	1,6	1,7	1,0	0,2	1,7	0,5	0,4	0,4	0,3	0,4	0,3
8 kHz	125,6	112,4	8,5	1,5	1,9	1,5	0,4	1,5	0,3	0,2	0,2	0,1	0,1	0,1

B.8 Measurement equipment

Microphone   XX

Sound level meter   XX

ADX converter   XX

Calibrator   XX

The calibration of the sound level meter was checked by XX

Measurement position 10 m from muzzle positioned for grazing incidence 1,5 m above ground

Shot gun   over and under barrel of 0,67 m full choke

Ammunition   special load of 24 g and a muzzle speed of 400 m/s, 400 pellets, mass of powder …

Manufacturer   XX

B.9 Measurement conditions

The temperature was 5 °C and the air pressure 1 020 hPa. The correction for meteorological standard conditions $A_Z = -0{,}1$ dB has been neglected.

B.10   Uncertainty contribution according to 11.2

The span of the measured A-weighted angular energy distribution levels was less than ±1 dB for each of the 8 measured positions. Each direction was measured 5 times. If a rectangular distribution is assumed, the variance is 0,33 dB.

Using Equation (17), the standard deviation of the measured angular source distribution level L_q can be estimated:

$$s_D{}^2 = \frac{8 \times 5}{8 \times 5 - 13}(0{,}33) = 0{,}5 \ \text{dB}^2 \tag{B.1}$$

The uncertainty contribution of measurement of the directivity is obtained using Equation (18) as follows:

$$\Delta_D = \frac{\sqrt{0{,}48} \times 2{,}04}{\sqrt{5}} = 0{,}6 \ \text{dB} \tag{B.2}$$

Using Equation (19), one obtains the measurement uncertainty contribution of the source energy due to the measurement

$$\Delta_Q = 0{,}2 \ \text{dB} \tag{B.3}$$

The uncertainty contribution resulting from other sources should be added as described in Annex C.

Annex C
(informative)

Guidance on the measurement uncertainty

C.1 General

The accepted format for expression of uncertainties generally associated with methods of measurement is that given in the GUM (*Guide to the Expression of Uncertainty in Measurement*) [6]. This format incorporates an uncertainty budget, in which the various sources of uncertainty are identified and quantified, from which the combined uncertainty can be obtained. The data necessary to enable a quantitative budget for this part of ISO 17201 were not available at the time it was being prepared. However, an indication is given below, based upon preliminary assessments, of the sources of uncertainty that are thought to be associated with the methods and equipment described. The general approach to calculation of uncertainties appropriate to this part of ISO 17201, conforming with the GUM, is illustrated for information.

C.2 Uncertainty of the angular source energy distribution level

C.2.1 Functional relationship

Preliminary estimations show that a general expression for the determination of the angular source energy distribution level, L_q, is given by the following equation:

$$L_q(\alpha_n) = L_E(r_m, \alpha_n) + A_{div}(r_m) + A_{atm}(r_m) + A_Z + A_{gr} + \delta_{slm} + \delta_{fw} - 11 \text{ dB} \qquad (C.1)$$

where

$L_E(r_m, \alpha_n)$ is the measured sound exposure level, expressed in decibels;

$A_{div}(r_m)$ is a correction for the geometric spread, expressed in decibels;

$A_{atm}(r_m)$ is a correction for air absorption, expressed in decibels;

A_Z is used to correct for non-standardized meteorological conditions, expressed in decibels;

A_{gr} is a correction in order to obtain free-field conditions, expressed in decibels; this includes the effect of the ground impedance;

δ_{slm} is an input quantity to allow for influences of the measuring instrumentation, expressed in decibels;

δ_{fw} is an input quantity to allow for uncertainties in the frequency weighting (A-weighting or one-third-octave filtering), expressed in decibels.

NOTE 1   The input quantities included in Equation (C.1) to allow for uncertainties are those thought to be applicable based on the knowledge at the time when this part of ISO 17201 was being prepared. Further research could reveal that there are others.

NOTE 2   In a given situation, input quantities considered to have only a negligible effect on the combined uncertainty might be disregarded in the uncertainty budget.

A probability distribution (normal, rectangular, Student t-value, etc.) is associated with each of the input quantities. Its expectation (mean value) is the best estimate for the value of the input quantity and its standard deviation is a measure of its variance (called standard uncertainty). These uncertainties contribute to the combined uncertainty associated with values of the source energy level.

C.2.2 Contributions to measurement uncertainty

The contributions to the combined uncertainty associated with the value of the angular source energy distribution level depend on the uncertainties and the related sensitivity coefficients, c_i. The sensitivity coefficients are a measure of how the values of the source energy level are affected by changes in the values of the respective input quantities. Mathematically they are equal to the partial derivative of the physical relationship with respect to the relevant input quantity. The contributions of the respective input quantities are then given by the products of the standard uncertainties and their associated sensitivity coefficients. Thus, the information needed from which to derive the overall uncertainty is that illustrated in Table C.1.

Table C.1 — Uncertainty budget for determinations of angular source energy distribution levels

Quantity	Estimate [a]	Standard uncertainty [a] u_i	Probability distribution [a]	Sensitivity coefficient c_i	Uncertainty contribution $c_i u_i$
	dB	dB			dB
$L_E(r_m, \alpha_n)$	$L_{E,est}(r_m, \alpha_n)$	u_1	d	1	u_1
$A_{div}(r_m)$	$A_{div,est}(r_m)$ [c]	u_2		1	u_2
$A_{atm}(r_m)$	$A_{atm,est}(r_m)$ [c]	u_3		1	u_3
A_Z	$A_{Z,est}$	u_4		1	u_4
A_{gr}	$A_{gr,est}$	u_5		1	u_5
δ_{slm}	b	u_6		1	u_6
δ_{fw}	b	u_7		1	u_7

[a] The estimate, the probability distribution and the resulting standard deviation, respectively, have to be estimated for each quantity based on information available or personal judgement.

[b] Usually, no corrections are applied to take these effects into account. The best estimate is then zero in each case.

[c] These terms may also be neglected due to the small contribution.

[d] Empirical part.

C.2.3 Combined and expanded uncertainty of measurement

The combined uncertainty for the determination of the angular source energy distribution level $u\left(L_q(\alpha_n)\right)$ is given by the following equation:

$$u\left[L_q(\alpha_n)\right] = \sqrt{\sum_{i=1}^{7} u_i^2} \qquad \text{(C.2)}$$

The GUM requires an expanded uncertainty, U, to be specified, such that the interval $[L_Q - U, L_Q + U]$ covers, for example, 95 % of the values of L_Q that might reasonably be attributed to L_Q. To that purpose, a coverage factor k is used, such that $U = k\,u$.

Table C.2 — Coverage factors associated with different coverage probabilities

Coverage probability %	Coverage factor
67	1,0
80	1,3
90	1,6
95	2,0
99,9	2,6

C.3 Uncertainty of the source energy level

The source energy level is calculated from the measured angular source energy distribution level by integration. This integration leads to a reduction of the uncertainties with respect to the uncertainties of the angular source energy distribution level. Therefore, the uncertainties for the source energy level may be assumed to be the same as uncertainties of the angular source energy distribution as described in C.2. Equation 18 represents a heuristic approach to account for the integration. All other contributions to the uncertainty budget as depicted in Table C.1 should be added to these uncertainties.

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[AC₁⟩ *Text deleted* ⟨AC₁]

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