INTERNATIONAL STANDARD

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Acoustics — Methods for the description and physical measurement of single impulses or series of impulses

Acoustique — Métrique et techniques pour le mesurage physique de bruits impulsionnels isolés ou en courtes rafales

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 10843 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

Annexes A to E of this International Standard are for information only.

Introduction

0.1 Purpose

The purpose of this International Standard is to describe and specify the physical measurement of single impulsive sounds or short series of impulsive sounds. The actual measurement performed will change according to both the measurement situation and the physical quantities required. Detailed characterization of source emissions is beyond the scope of this standard.

0.2 Physical measurement alternatives

Physical measurement alternatives will change according to the purpose of the measurements and the measurement situation. First, measurements may be made of phase-sensitive quantities such as peak-level, rise-time, or duration, or measurements may be made of time-integrated quantities such as frequency-filtered or frequency-weighted sound exposure level (e.g. A-weighted sound exposure level). Secondly, measurements may be made on a continuous sound source or a transient sound source. This International Standard deals only with transients (single impulsive sounds or short series of impulsive sounds); therefore time-integrated descriptors such as sound exposure or sound energy, rather than time-averaged descriptors, are applicable.

0.3 Measurement situation

Noise measurement situations will change according to the purpose of the measurement. There are three alternative pairs of measurement situations which may require the measurement of single impulsive sounds or series of impulsive sounds. First, measurements may be for workplace-related purposes, such as hearing conservation or employee efficiency, or measurements may be for community environmental purposes. Secondly, measurements may be indoors or outdoors. Thirdly, measurements may be for the purpose of gathering source-emission data, or of describing immission levels in the community. Other International Standards provide guidance for specific measurement situations. ISO 11200 should be used for measurements of emission sound pressure levels at the work station and at other specified positions; the ISO 3740 or ISO 9614 series should be used for determination of sound power levels of noise sources; the ISO 1996 series should be used for description and measurement of environmental sound.

Acoustics — Methods for the description and physical measurement of single impulses or series of impulses

1 Scope

This International Standard describes preferred methods for the description and the physical measurement of single impulsive sounds or short series of impulsive sounds and for the presentation of the data. It does not provide methods for interpreting the potential effects of series of impulses of noise on hearing, community response or structures.

This International Standard applies to single impulsive sounds or short series of impulsive sounds such as those produced by explosions, artillery fire, bombing and similar activities, sonic booms, pistol and rifle fire, and cartridge-operated tools or machines.

Two different kinds of measurements are considered:

a) measurements of phase-sensitive parameters, such as peak sound pressure level and duration, that directly characterize the variation of sound pressure with time; and

b) measurements of time-integrated quantities such as frequency-weighted sound exposure level or sound energy level.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 50-801:1994, *International electrotechnical vocabulary — Chapter 801: Acoustics and electroacoustics*

IEC 651:1979, *Sound level meters,* and its Amendment 1:1993.

IEC 804:1985, *Integrating-averaging sound level meters*, and its Amendment 1:1989 and Amendment 2:1993.

IEC 942:1988, *Sound calibrators.*

IEC 1260:1995, *Electroacoustics — Octave-band and fractional-octave-band filters.*

3 Definitions

For the purpose of this International Standard, the definitions given in IEC 50-801 and the following definitions apply.

NOTE — The prefix "un" is used to denote what is also termed "lin-" or "flat-" weighted sound. Unweighted is perhaps most descriptive.

3.1 Characteristics of an impulse noise

3.1.1 A-duration: Time, in seconds, required for the main or principal wave to reach its unweighted peak sound pressure and return momentarily to zero.

NOTES

1 See figure 1 a) and annex E, reference [25].

2 In practice, the A-duration is the total time between the onset of a signal level 20 dB below the peak level and the first crossing of the signal 20 dB below peak level.

3 The notation used for duration in this definition and in 3.1.2 and 3.1.3 should not be confused with the A-, B- and C-frequency weightings.

3.1.2 B-duration: Total time, in seconds, that the envelope of unweighted sound pressure fluctuations (both positive and negative) exceeds one tenth of the unweighted peak sound pressure, including the duration of that part of any reflection pattern that exceeds one tenth of the unweighted peak sound pressure.

NOTE — See figure 1 b) and annex E, reference [25].

3.1.3 C-duration: Total time, in seconds, that the main or principal wave and the following oscillations, both negative and positive, are within 10 dB of the unweighted peak sound pressure level.

NOTE — See figure 1 c) and annex E, reference [34].

3.1.4 envelope: Two idealized smooth lines which effectively join the successive positive or negative peaks of the instantaneous sound pressure.

NOTE — See figure 1 d).

3.1.5 impulse noise: A single short burst or series of short bursts of sound pressure.

NOTE — The pressure-time history of a single burst of impulsive noise includes a rise to a peak pressure, followed by a decay of the pressure envelope.

3.1.6 instantaneous sound pressure: Total instantaneous pressure, in pascals, at a point in the presence of a sound wave minus the atmospheric pressure at that point.

NOTE — Instantaneous pressure relates to the pressure as measured by the microphone prior to any signal processing.

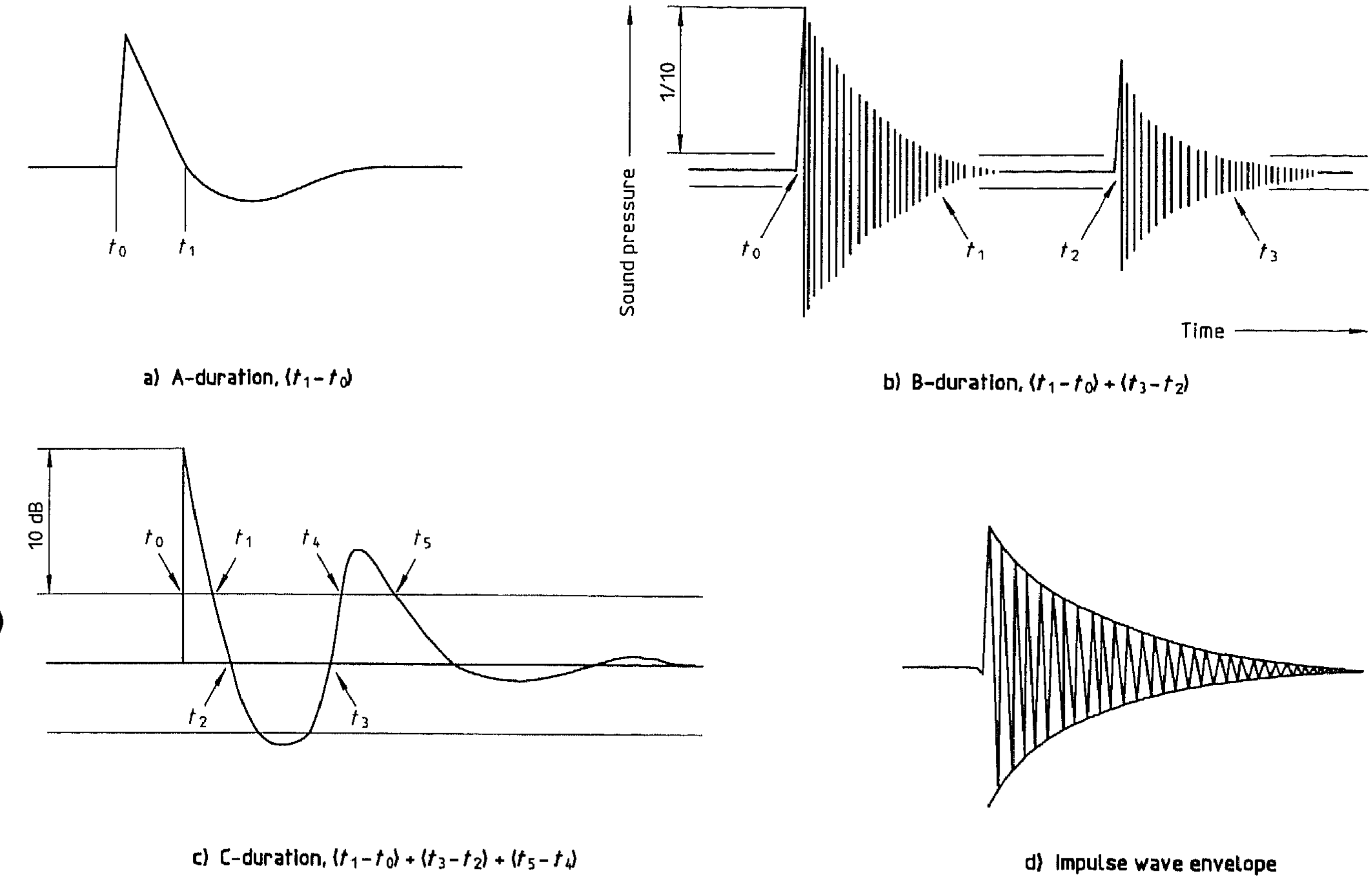


Figure 1 — Impulse noise characteristics

3.1.7 instantaneous sound pressure level: Ten times the common logarithm of the square of the ratio of the frequency-weighted instantaneous sound pressure to the reference sound pressure, expressed in decibels.

NOTES

1 In air the reference sound pressure is 20 µPa.

2 The frequency weighting is to be specified.

3.1.8 peak sound pressure: For any specified time interval, the maximum absolute value of the instantaneous sound pressure, in pascals, that occurs during a specified time interval.

3.1.9 peak sound pressure level: Ten times the common logarithm of the square of the ratio of peak frequency-weighted sound pressure to the reference sound pressure, expressed in decibels.

NOTES

1 In air, the reference pressure is 20 µPa.

2 The frequency weighting is to be specified.

3.1.10 signal rise time: Time, in seconds, a signal takes to rise from 10 % to 90 % of its maximum absolute value of the sound pressure.

3.1.11 sound energy: Time and spatial integral of the sound intensity normal to an imaginary closed surface, where sound intensity is the real part of the product of instantaneous sound pressure and particle velocity (at the same point in space), expressed in joules.

3.1.12 sound energy level: Ten times the common logarithm of the ratio of sound energy to the reference sound energy of 1 pW·s, expressed in decibels.

3.1.13 sound exposure: Time integral of frequency-weighted squared instantaneous sound pressure, expressed in pascal-squared seconds.

$$E = \int_0^T p^2 \, dt \qquad \text{...(1)}$$

NOTE — The frequency weighting is to be specified.

3.1.14 sound exposure level: Ten times the common logarithm of the ratio of sound exposure, E, to the reference sound exposure, expressed in decibels.

$$L_E = 10 \lg\left(\frac{E}{E_0}\right) \text{dB} \qquad \text{...(2)}$$

NOTES

1 In air, the reference sound exposure, E_0, is 20 μPa²·s.

2 The frequency weighting is to be specified.

3 In order to avoid confusion between the noise exposure of workers and the noise emission from machinery, in the ISO 3740 series and ISO 11200, which are specific to machinery noise emission, this quantity is called "single-event emission sound pressure level."

3.2 Characteristics of the measurement system

3.2.1 bandwidth: Frequency range, in hertz, over which the response of a system to a sinusoidal input signal is within zero to –3 dB of an ideal flat response.

NOTE — This definition is specific to the purposes of this International Standard and not necessarily in accordance with more general definitions given in other International Standards.

3.2.2 droop: Amount by which the linear system output drops below the ideal final output in response to a step-function input when measured at a time which equals or exceeds the duration of the signal of interest, divided by the ideal final output and expressed as a percentage,.

3.2.3 dynamic range: Difference, in decibels, between the peak signal level (unweighted), expressed as the sound pressure level for which the measurement system operates within the instrument manufacturers' stated specifications, and the measurement system background noise level (unweighted), expressed as the sound pressure level.

NOTES

1 At low sound pressure levels the useful dynamic range is limited by acoustic noise or by electric circuit noise.

2 At high sound pressure levels the useful dynamic range is limited by overloading of the microphone or the electronic instrumentation.

3.2.4 overshoot: Amount by which the maximum of the linear system output exceeds the idealized final output in response to a step-function input, divided by the ideal final output and expressed as a percentage.

3.2.5 slew-rate: Rate of change of the measurement system output per unit time, expressed in volts per second.

3.2.6 slew-rate limit: Maximum rate of change of the measurement system output in response to a step-function input, expressed in volts per second.

3.2.7 system rise time: Time, in seconds, required for the linear system output to rise from 10 % to 90 % of its final amplitude in response to a step-function input.

4 Measurement system characteristics and requirements

4.1 General

This section does not specify general instruments for measuring impulsive sound. The purpose of this section is to specify the system characteristics required to accurately measure impulsive sound for any particular purpose.

The measurement system characteristics and requirements change according to the purpose of the measurement. For example, a type 1 integrating-averaging sound level meter, fitted with a microphone of type WS2 according to IEC 1094-4, might be used to measure the A-weighted sound exposure level from a short burst of pneumatic-hammer sound. The same sound level meter, fitted with a sealed microphone of type WS1, might be used to measure the unweighted peak sound pressure level of a mining explosion. This section describes the characteristics and accuracy required for measuring the time-varying and time-integrated characteristics of impulsive sound. These requirements permit the user to select and tailor a measurement system to the measurement purpose. See also annexes A and C.

The measurement system includes all equipment from the microphone and its windscreen, if used, to the instrument that indicates the results of the measurement. If tape-recording is employed, the system includes the recording and playback equipment as well as the tape itself.

The accuracy attained in the measurement of impulsive sound depends upon the instruments used, the measurement procedure, and the characteristics of the particular impulse sound. Information on measurement procedures is given in clause 5.

4.2 Requirements for measurement of phase-sensitive quantities

Five characteristics are important for describing an impulsive sound in the time domain: system rise time, overshoot, droop, dynamic range and bandwidth. Depending on the type of impulsive sounds being measured, some instrument characteristics may be more important than others. For example, an impulsive sound having a long A-duration need not be measured with instruments which meet the rise time requirement of 4.2.1 if only the A-duration is to be measured.

4.2.1 System rise time

The system rise time should be less than one-tenth of the rise time of the impulsive sound. For sounds having extremely short rise times (e.g. shock waves), it may not be possible to meet this recommendation.

NOTE — For shock waves which have near-zero rise time, the systematic error in the measurement of the peak pressure may be estimated by multiplying the indicated peak pressure by

$$K = 1 + \frac{T_r}{T_a}$$

where

T_r = system rise time, in seconds;
T_a = A-duration, in seconds.

That is, the estimated actual peak sound pressure equals K times the indicated pressure.

4.2.2 Overshoot

The overshoot in response to a step-function input should be less than 5 %.

NOTE — Overshoot is really an instrument requirement which is independent of the waveform being measured. It is included here for completeness.

4.2.3 Droop

The system droop in response to a step-function input shall be less than 5 % during a time period equal to the A-duration of the signal.

4.2.4 Dynamic range

The system dynamic range shall include at least the interval from 1 dB above the peak sound pressure level of the signal to 5 dB below the minimum sound pressure level of interest.

4.2.5 Phase distortion and bandwidth

The phase distortion of the measurement system in the frequency range of interest shall be limited to ± 10°. This requirement is normally fulfilled when the bandwidth includes the frequency range from one decade below the lowest frequency of interest to one decade above the highest frequency of interest. Otherwise the phase distortion for the highest frequency of interest shall be reported.

NOTES

1 Phase response is directly related to the complexity of the frequency limiting mechanisms (electrical, mechanical and acoustical) and, in complicated situations, a much greater bandwidth may be required.

2 To measure peak values and other phase-sensitive quantities, filters should be operating in "real time". Filters should be linear and the group delay should be constant. FFT analysis and the "reconstitution" of filters is inappropriate.

4.3 Requirements for measurement of time-integrated quantities

This subclause gives requirements for the measurement of the sound exposure level or sound energy level.

4.3.1 Dynamic range

The system dynamic range is specified in 4.2.4.

4.3.2 Time-integration

4.3.2.1 Single time periods

For measurements of sound exposure level, the analogue of the squared (frequency-weighted) instantaneous sound pressure shall be integrated over the duration of the impulse or series of impulses of sound. The integration period shall be selected such that the background noise influences the measured sound exposure level by less than 0,5 dB. The duration of the integration period shall be measured to within an uncertainty of ± 5 %.

4.3.2.2 Multiple time periods

For a series of separate impulsive sounds, where a series of short integration periods are used to build up a longer period or where short duration sound exposure values are used to generate other metrics, each integration period shall effectively include its corresponding single impulse or series of impulses of sound. Collectively, integration periods shall be selected such that the background noise influences the total measured sound exposure level by less than 0,5 dB. Each integration period shall be determined to an uncertainty of ± 0,01 %.

NOTE — The uncertainty of time measurement in 4.3.2 is really an instrument requirement which is independent of the waveform being measured. It is included here for completeness.

4.3.3 Digital integration

If digital integration is used, the sampling rate should be at least three times the highest frequency of interest.

NOTE — It is possible that the frequency of interest does not include the highest frequencies in the signal. If frequencies exist which are above the Nyquist frequency, then filtering should be used to prevent an aliased signal.

4.3.4 Linearity range and resolution

Linearity range and resolution shall be in accordance with the requirements of IEC 651 and IEC 804. The linearity range shall be sufficient to accommodate the peak signal level without substantially increased distortion or clipping.

NOTE — The linearity range should be at least 25 dB plus ten times the common logarithm of the ratio of the integration period to the duration of the signal.

4.3.5 Minimum bandwidth

The minimum bandwidth shall extend from the lowest frequency of interest to the highest frequency of interest.

4.3.6 Frequency weighting

Instrumentation systems which include A- and C-weighting filters shall meet the requirements of IEC 651 for type 1 instruments; they should preferably meet the requirements for type 0 instruments.

4.3.7 Filters

Octave and one-third-octave-band filters shall satisfy the requirements of IEC 1260.

NOTE — This International Standard does not specify specific frequency weightings or filtering since these will vary according to the source and purpose of the measurement. For example, for indoor factory noise control design, octave or one-third-octave data may be required. Frequently, A-weighting will be used to characterize a noise for purposes of environmental noise assessment or hearing conservation. In some countries, AI-weighted sound pressure levels are used to quantify general, impulsive sound sources. In some countries, C-weighting is used for outdoor characterization of high-energy impulsive sound sources such as artillery and sonic booms. In many countries, the peak C-weighted instantaneous sound pressure level is specified for rating impulsive sound, for example, in the European Community Machinery Directive 89/392/EEC.[40]

4.4 Determination of measurement system characteristics

Guidance on determination of measurement system characteristics is given in annex C.

4.5 Instrumentation

4.5.1 Requirements

4.5.1.1 Sound level meters and similar measurement devices shall comply with the type 1 requirements of IEC 651 and IEC 804 and should comply with the additional requirements of annex D. If a digital or analogue recording instrument is used for (intermediate) storage, it shall have a bandwidth meeting the requirements of 4.2.5 and 4.3.5.

NOTES

1 Instruments meeting the requirements of IEC 804 are preferred for integrated measurements because of their wider dynamic range.

2 When the impulses are short, the maximum value of the time- and frequency-weighted sound pressure level can be estimated directly from a sound level meter provided that the impulse duration (including virtually all reflected and reverberant sound) is shorter than 0,2 τ, where τ is the time constant of the time weighting (τ = 35 ms for time weighting I, τ = 125 ms for time weighting F, τ = 1000 ms = 1 s for time weighting S).

Conversion to a single-event sound exposure level (SEL) can be estimated by adding

$$10 \lg \left(\frac{\tau}{1 \text{s}} \right) \text{dB}$$

For example, for A-weighted events,

— for time weighting I: $L'_{AE,\,1s} = L'_{pAImax} - 14{,}6$ dB

— for time weighting F: $L'_{AE,\,1s} = L'_{pAFmax} - 9$ dB

— for time weighting S: $L'_{AE,\,1s} = L'_{pASmax}$

This method of determining the sound exposure level for short-duration impulsive sounds makes use of the fact that an "RC" network with time constant τ acts like an integrator during its initial transient response. When using this method to measure the SEL of a short-duration transient, it is particularly important to ensure that the sound level meter time-weighting network truly approximates an RC averaging network, and that the time constant is accurately known. As indicated above, any error in specifying the time constant directly results in a corresponding error in the calculated sound exposure level. Requirements for these time-weighting networks are given in IEC 651 and in annex D.

4.5.1.2 For the measurements of peak sound pressure level or maximum (frequency-weighted) sound pressure level, a sound level meter or similar device shall be equipped with "HOLD" circuitry.

4.5.2 Microphone size and orientation

The diameter and orientation of the microphone are important when measuring short-duration impulsive sounds. Small-diameter microphones should be used in order to limit the transit time of the wave across the sensing surface; use of microphones larger than type WS2 according to IEC 1094-4 should be avoided. The microphone should be such that its flattest response is for grazing incidence (i.e. the P type according to IEC 1094-4), and it should be fitted with a protection grid. The microphone should be oriented for grazing incidence. For microphones of type WS3 or smaller (over the audio frequency range), use of a protection grid causes only slight differences. For longer duration events such as blasts or sonic booms, adequate microphone low-frequency response is important to prevent excessive droop and resulting error in measurement of the negative part of the signal. Microphones of type WS1 may be required for this purpose.

NOTE — If an F type microphone is used, it should be oriented for normal (0°) incidence. However, in terms of transient response a microphone diaphragm may ring more from transient excitation at normal incidence than from transient excitation at grazing incidence. Hence, a P type microphone and grazing incidence is preferred.

4.5.3 Windscreens

The use of windscreens or rain covers should be avoided, if possible, when measuring impulsive noises having high-frequency components that may be excessively absorbed by such devices. When their use is necessary, such as for outdoor measurements, they become a part of the system and should be tested in accordance with the procedures given in annex C.

NOTE — If the windscreen and/or rain cover do not obstruct or in any way change the back air vent of the microphone, then it should not be necessary to test for droop caused by windscreen and rain cover.

4.6 Calibration

System calibration shall include the response of all cables, amplifiers, and accessories to be used when actual data are taken. Calibration shall be accomplished at appropriate times to ensure that time-average 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 an acoustical calibration is accomplished before and after field use. Electrical signals should be inserted into the microphone input via a suitable adapter.

NOTES

1 Annex B provides guidance on large-amplitude (above about 135 dB) impulse calibration of sealed, low-frequency microphones and associated preamplifiers in a laboratory setting. These methods can be used before any measurement program.

2 For phase-sensitive measures, if the system bandwidth fails to meet the requirements of 4.2.5, then laboratory measurements of the system phase response should be performed.

5 Measurements

5.1 General

As discussed in clause 4, system requirements are defined by the signal quantity to be measured and depend on the characteristics of the waveform itself. For example, measurement of the rise time associated with the excitation of a spark source requires a much shorter system rise time than does measurement of a sonic boom produced by a high-flying supersonic aircraft. On the other hand, measurement of the A-duration of these respective signals requires a far smaller droop for accurate measurements of a sonic boom than for measurement of the time variation of the sound produced by the spark source.

5.2 Measurement conditions

Measurements can be made for a wide variety of purposes. As discussed in the introduction, the actual measurement performed will change according to

(a) the measurement situation, and

(b) the physical quantities required.

For example, source emissions vary considerably based on the type of source. Impulsive sound sources may vary from indoor factory machinery where the concern may be hearing loss prevention, to large field artillery where the concern may be a fairly distant community. Detailed characterization of source emissions are beyond the scope of this International Standard.

5.3 Procedures

5.3.1 Calibration

Field calibration shall be accomplished before and after each test sequence. This should be accomplished using a sound calibrator in accordance with IEC 942, Class 1.

NOTE — Annex B gives guidance on large-amplitude impulse calibration of microphones in a laboratory setting. These methods are intended for very low-frequency, sealed microphones and associated preamplifiers and can be used prior to any measurement program of this type.

5.3.2 Integration time

For measurements of the frequency-weighted or filtered sound exposure or the sound energy level of an event, the integration period shall be:

a) short enough to ensure that the background sound exposure or sound energy level is at least 10 dB below the actual sound exposure or sound energy level of the event, and

b) long enough to ensure that 90 % of the area under the curve of squared pressure or power versus time is included.

5.4 Background noise

Care shall be taken to ensure that background noise, including wind-induced pseudo-noise, does not affect the reported results. For single impulsive sounds and short series of impulsive sounds, it is usually possible to "edit" the measurement to include just the time when the impulsive sound(s) occur. In this way, the effects of background noise can be minimized.

5.4.1 Time-integrated quantities

For measurements of frequency-weighted or filtered sound exposure, the measured sound exposure level for the source or situation in question shall exceed the measured background level by 10 dB. If the measurement fails to meet this requirement, the reported results shall be corrected by subtracting the background level from the source or situation level on an energy basis. Table 1 and equation (3) give these corrections. In all cases, the measured level shall exceed the background level by at least 3 dB. To the extent practical, both measurements shall be made at the same site, with the same equipment, as near in time as possible to each other, and for the same duration. If possible, both measurements should be made within at least one hour of each other. The situation shall be described.

Table 1 — Correction for background noise

ΔL dB	3	4	5	6	7	8	9	10	> 10
K_1 dB	3,0	2,2	1,7	1,3	1,0	0,7	0,6	0,5	0

$$K_1 = -10 \lg(1 - 1/10^{0,1\Delta L}) \text{ dB} \quad \text{... (3)}$$

In table 1 and equation (3), ΔL is the difference, in decibels, between the source or situation level and the background level, and K_1 is the correction, in decibels, to be subtracted from the measured source or situation level.

5.4.2 Phase-sensitive quantities

For measurement of phase-sensitive quantities, the impulsive sound shall be such that the lowest level of the portion of interest of the waveform is at least 5 dB above the level of the background noise and within the dynamic range limits of the system.

NOTE — For measurement of the time of a "zero crossing" (when the sound pressure changes sign), this background noise level requirement defines a range of uncertainty for the measurement.

5.5 Uncertainty

No significance can be attached to a measurement of any quantity unless its uncertainty is known. Such information is especially important when the purpose of the measurement is to decide whether a product is acceptable to a purchaser or even whether it conforms with legal requirements. No matter which physical quantity is being measured, the result is derived from a complex situation and can be affected to a significant degree by the acoustical environment, the measurement equipment and the operating conditions of the source. Methods of the kind given in ISO 7574 and in the BIPM/IEC/IFCC/ISO/IUPAC/IUPAP/OIML guide[25], should be used to estimate the measurement uncertainty, that is the range within which the true value is estimated to lie, at a given confidence level.

NOTE — ISO 3740 on the determination of sound power levels of machinery gives values of the standard deviation of reproducibility.

6 Data presentation

All instruments, including those used for data presentation, shall meet the measurement system requirements given in clause 4.

6.1 Phase-sensitive quantities

6.1.1 General

Phase sensitive quantities include peak sound pressure, A-duration, B-duration, C-duration and rise time. These quantities may be obtained from pictorial displays of the entire pressure-time history using oscilloscopes or similar instruments. The test report shall describe the entire measurement system with specific reference to the characteristics in 4.2.

6.1.2 Frequency description or weighting

When frequency weighting networks or filters are used to modify the frequency response in a defined way, data or pictorial records shall be identified in terms of that frequency weighting network or filter (e.g. peak C-weighted sound pressure level).

When band pass filters other than those complying with IEC 1260 are used, the test report shall define the attenuation rate outside of the pass band over the frequency ranges from each band-edge frequency to at least 60 dB below the minimum transmission response in the pass band. When no frequency weighting networks or filters are used to limit the frequency response in a defined way, data or pictorial records shall include a specific notation of the limiting factors such as bandwidth or system rise time.

6.2 Time-integrated quantities

Time-integrated descriptors include such quantities as frequency-weighted sound exposure level and sound energy level. The test report shall describe the entire measurement system with specific reference to the requirements in 4.3.

6.2.1 Frequency description or weighting

When frequency-weighting networks or filters are used to modify the system frequency response in a defined way, the measured quantity shall be identified in terms of frequency weighting or filter bandwidth. The measurement frequency band shall be reported by stating the standardized frequency weighting, the bandwidth and centre frequency, or the band limits. The measurement duration or the beginning and ending measurement times shall be reported.

EXAMPLES

1 2 min, 1 000 Hz one-third-octave-band sound exposure level

2 35 s, 175 Hz to 610 Hz band sound exposure level

When no frequency weighting networks or filters are used to limit the system frequency response in a defined way, the test report shall include a specific notation of limiting factors such as the frequency response of the microphone and the bandwidth of the measurement system.

6.2.2 Spectra

The frequency content of a transient event shall be described by the sound exposure level in constant percentage bandwidth (e.g. one octave or one-third octave) or in constant bandwidth (e.g. one hertz).

6.2.3 Measurement duration

For sound exposure or sound energy, the measurement duration or the beginning and ending measurement times shall be reported.

6.3 General site and procedural information

6.3.1 Calibration

The report shall include the results of instrument calibrations performed before and after the measurements. For measurements lasting well over one hour, additional calibrations shall be made and shall be reported at approximately hourly intervals.

6.3.2 Meteorological conditions (outdoor measurements)

The report shall include

(a) wind speed and direction;

(b) ambient temperature;

(c) relative humidity; and

(d) barometric pressure

before and after the measurements.

For measurements at a large distance from the source, additional meteorological data shall be reported, such as temperature and wind velocity gradients.

6.3.3 Site description

The report shall include:

a) a physical and topographical description of the measurement surface in the vicinity of the measurement site;

b) a map indicating the measurement site location(s) and another map (possibly more detailed) indicating the approximate location of the noise source(s) with respect to the microphone positions;

c) a diagram of the measurement site area including the location of reflective surfaces near the microphone position(s);

d) a description of the sound source(s) and their operating conditions.

Annex A
(informative)

Signal handling limitations in transient measurement and analysis

Waveform distortion can occur during transient analysis if the signal rate of change over time falls outside a specified range. Any portion of the signal waveform with a slope greater than the slew-rate limit of any given amplifier will be distorted into a straight line segment with slope equal to the slew-rate limit. Conversely, long duration pulses can vary so slowly that the amplifier output "droops". This annex provides information that relates these forms of distortion to instrument performance specifications so that these limitations can be recognized and avoided.

A.1 Slew-rate limit of amplifiers

The slew-rate limit gives the maximum rate of change possible for an amplifier's output voltage. The limit usually occurs when a phase compensation capacitor begins to charge at the maximum rate set by the current available. The slew-rate varies from 5×10^5 V/s for general-purpose operational amplifiers to 2×10^9 V/s for wide band amplifiers. The effects of the slew-rate limit on short-duration and steadily fluctuating signals will now be considered (see annex E, reference [35]).

All signals can, in theory, be represented by a combination of many sinusoidal signals, each having different amplitudes, frequencies, and phases. The maximum sine wave frequency f_m, in hertz, which an amplifier can sustain without causing the output to take on a triangular shape, is a function of the amplitude of the sinusoidal output waveform and is expressed by

$$f_m = \frac{S_r}{2\pi U} \quad \text{... (A.1)}$$

where

S_r is the slew-rate limit, in volts per second;

U is the output sinusoidal amplitude, in volts.

For a given S_r the amplifier will distort the output signal if the product of $(2\pi U)f_m$ is greater than this S_r.

Closely related terms which are frequently used are the large-signal frequency limit and the full-power bandwidth. The large-signal frequency limit f_x is the highest frequency at which the amplifier will deliver an undistorted output voltage. It is found by using equation (A.1) with U equal to the maximum output voltage of the amplifier. Likewise, the full-power bandwidth B_x is the frequency range over which full undistorted power can be delivered, and is given by

$$B_x = f_x - f_1 \quad \text{... (A.2)}$$

where

f_x is the large-signal frequency limit, in hertz;

f_1 is the lower band-edge frequency, in hertz.

For example, a general-purpose operational amplifier might have the following characteristics:

$S_r = 5 \times 10^5$ V/s

$U = 13{,}5$ V

$f_1 = 0$ Hz

$f_x = B_x = 5,9 \times 10^3$ Hz

$f_m = 5,9 \times 10^3$ Hz

The step-voltage response of the amplifier may also be affected by the slew-rate limit. Most amplifiers have a frequency response that is flat to an upper band-edge frequency after which the response falls off at the rate of approximately 6 dB per octave. The rise time T_r for such amplifiers is

$$T_r = \frac{0,35}{f_2} \quad \text{... (A.3)}$$

where f_2 is the upper band-edge frequency, in hertz (Hz).

Normally, the rise time is independent of the magnitude of the voltage step U_s. However, the voltage becomes large enough to "slew-rate limit" the measurement system when

$$\frac{U_s}{T_r} = S_r \quad \text{... (A.4)}$$

The output will then be a ramp function with a slope of S_r. The limiting voltage step can be expressed as

$$U_s = \frac{0,35\,S_r}{f_2} \quad \text{... (A.5)}$$

A.2 Droop

For droop to be less than 5 %, the duration D of a pulse is limited by

$$D \leqslant \frac{0,05}{2\pi f_1} \quad \text{... (A.6)}$$

A.3 Small signal bandwidth

The small-signal bandwidth is the frequency range over which the amplifier response to a sinusoidal input signal is within 0 dB to –3 dB of the maximum response provided there is no slew-rate limiting. The transition voltage from "small" signals to "large" signals is found by substituting the upper band-edge frequency f_2 into equation (A.1). Signals less than U in amplitude are considered small; the range of frequencies for such signals is called the small-signal bandwidth or more simply, the bandwidth,

$$B = f_2 - f_1 \quad \text{... (A.7)}$$

Annex B
(informative)

Methods for the large-amplitude impulse calibration of microphones

B.1 General

This annex describes a method for calibrating microphones which are to be used to measure high-amplitude, low-frequency transients. Since the method provides for direct measurement of the step-function response of the system, it provides both a gain calibration and a direct measurement of the low-frequency response of the entire system. This method is intended primarily for un-vented microphones or for microphones for which the vent has been sealed so as to obtain low-frequency performance.

B.2 Description of the method

The microphone is enclosed within a thin membrane which is inflated to the required pressure. The membrane is then burst, allowing the air to quickly escape, thus presenting a step-function decrease in pressure to the microphone. The microphone output voltage is observed and stored on a suitable device such as a storage oscilloscope as it rises to a peak value (or decays to a negative "peak") and then decays to zero. The time constant of the decay curve is measured and used to calculate the microphone system's low-frequency response. The maximum, near-instantaneous change in voltage when the membrane is burst directly corresponds to the initial pressure (with respect to the atmospheric pressure) within the membrane before it is burst.

B.3 Implementation of hardware

One way to implement this method (for a microphone of type WS1) is shown in figures B.1 and B.2.

a) The microphone and follower amplifier fits within the apparatus. An "O-ring" within the apparatus forms a seal to the microphone follower amplifier.

b) The membrane is placed on the outside of the apparatus and inflated by introducing air through the small supply tube within the wall of the apparatus.

c) A small electric or manual air pump is connected to the pump line and a manometer (typically a slant-tube manometer) is connected to its connection point.

d) A storage oscilloscope or other similar device is connected to the output of the microphone follower (usually through a microphone power supply).

Dimensions in millimetres

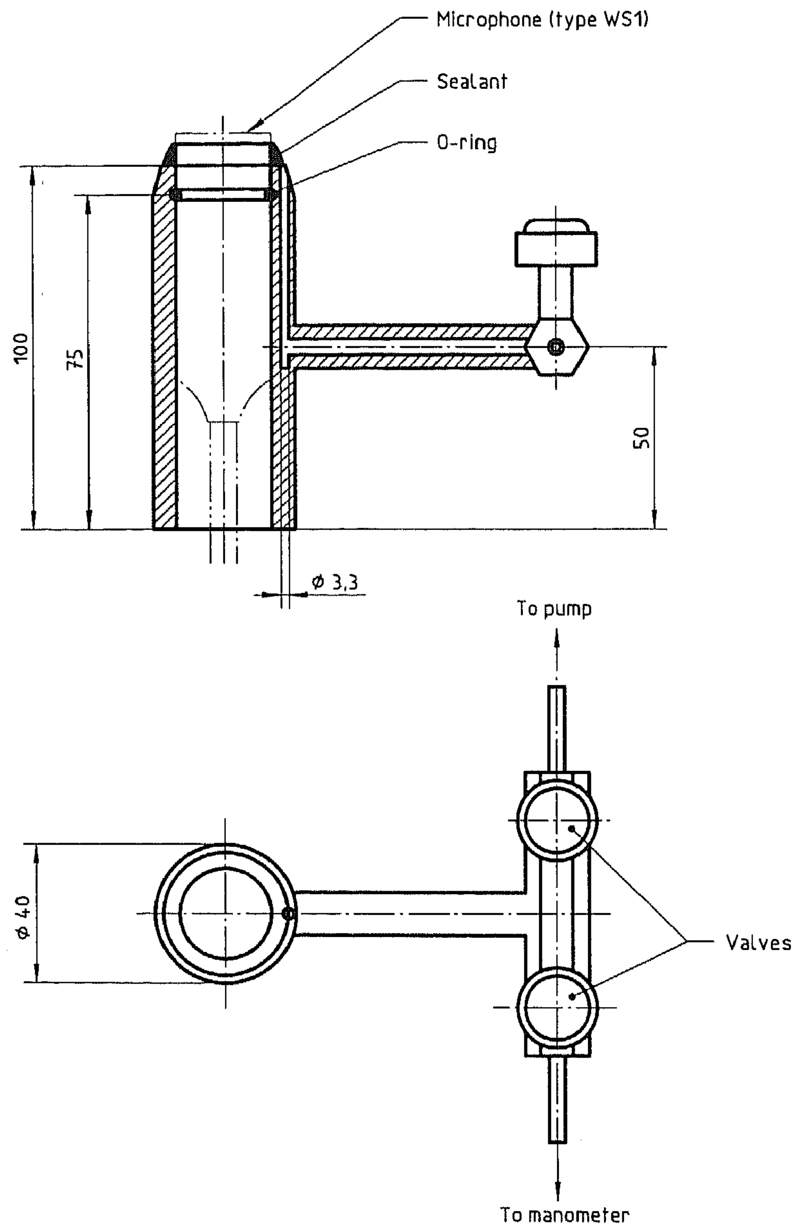
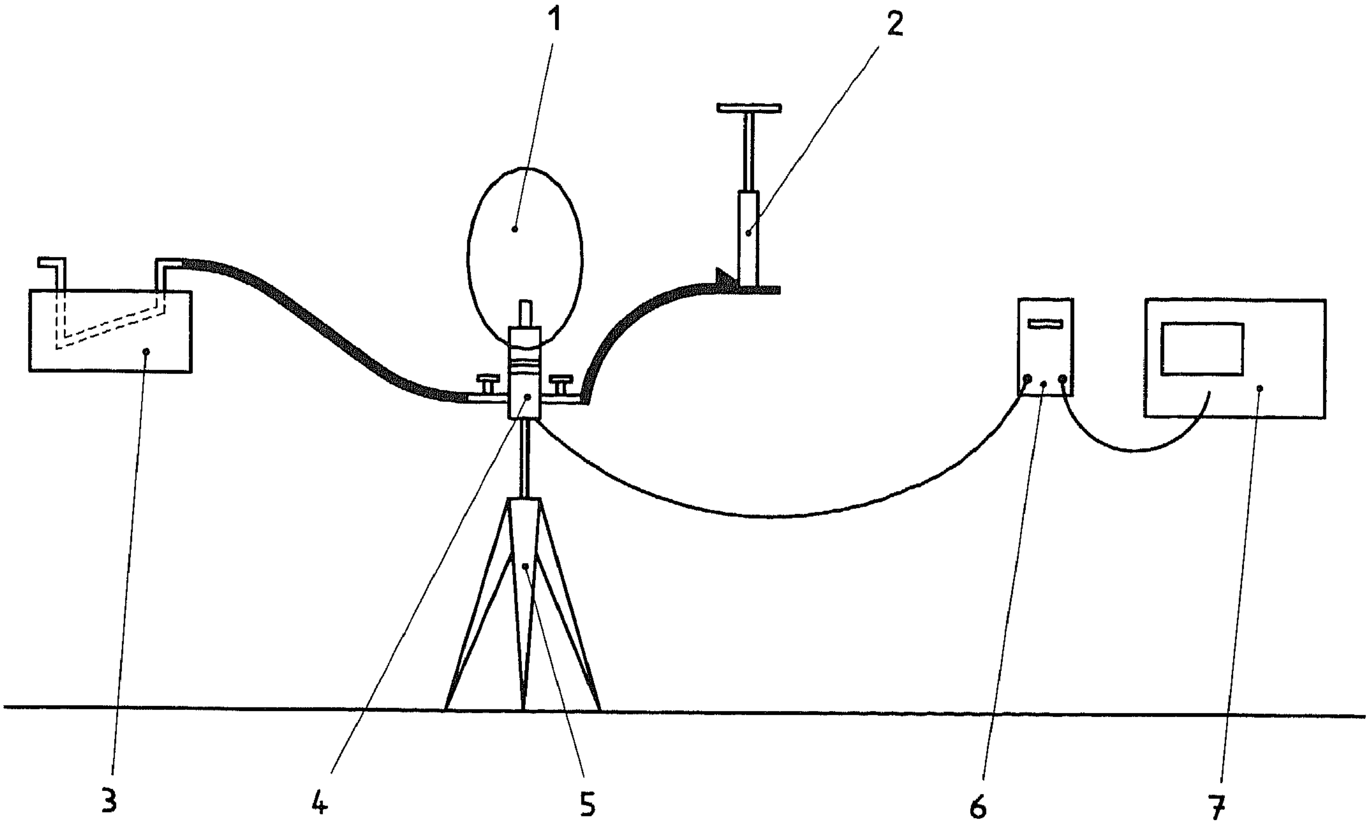


Figure B.1 — Example of adaptor



Key

1 Membrane
2 Air pump
3 Manometer
4 Adaptor with follower inside
5 Tripod
6 FM carrier
7 Oscilloscope

Figure B.2 — Example of calibration equipment

B.4 Procedure

a) Select a membrane which will inflate at the desired calibration sound pressure level, typically between 135 dB and 175 dB.

b) With all hardware in place and both valves open, inflate the membrane.

c) Close the pump valve and record the static pressure, in pascals.

d) Close the manometer valve and burst the membrane using a flame or other device which will not alter the inflated membrane volume before bursting.

NOTE — A pointed object will decrease the volume (increase the pressure) until the elastic limit of the membrane is reached and the pointed object breaks the membrane.

e) The recorded microphone output (figure B.3) directly shows the near-instantaneous change in voltage, and the low-frequency time constant is readily calculated. The ratio of the near-instantaneous change in voltage to the static pressure in the membrane before it is burst is the microphone sensitivity, in volts per pascal.

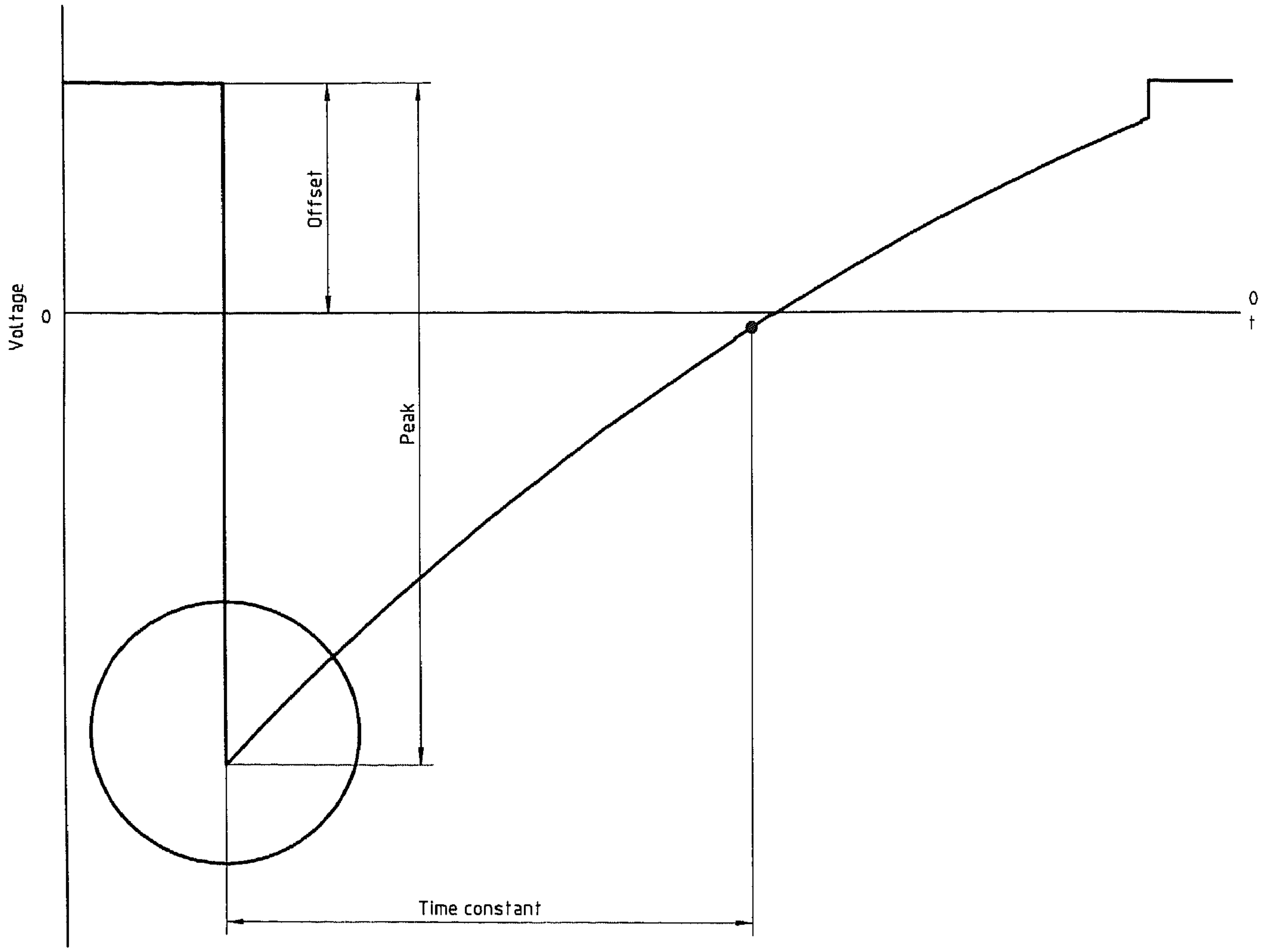


Figure B.3 — Microphone response curve

Annex C
(informative)

Determination of measurement system characteristics

The tests of C.1, C.2, and C.3 are necessary to determine phase-sensitive quantities such as peak sound pressure. The tests of C.3 and C.4 are necessary when determining time-integrated quantities.

C.1 System rise time capability

System rise time characteristics may be determined by measuring the sound pressure of shock waves such as those produced by a spark source, a cap pistol, or some other shock source (see annex E, reference [4]).

The electrical portion of the measurement system can be further tested by replacing the microphone with an equivalent impedance and by inserting a square wave impulse to the input at or above the amplitude of the signal to be measured. The leading portion of the time history produced by a square wave indicates the electrical system's rise time capability and overshoot.

C.2 Droop

The droop of the electrical portion of the measurement system can be determined with a low-frequency (long-duration) square wave. Acoustically, the total system droop may be determined by inserting the microphone into a small sealed cavity in which a rapid change in pressure is produced (see annex E, reference [5]). In this manner an acoustical step function is used to excite the system. For very low frequencies (e.g. below 1 Hz), the droop may be determined by quickly changing the microphone elevation over a distance of approximately 1 m.

NOTES

1 Changing the microphone height may be affected by wind and/or air viscosity.

2 Annex B provides additional guidance on the measurement of droop for very low-frequency situations using the sealed cavity.

C.3 Frequency response

The frequency response shall be tested in accordance with the procedures of IEC 651:1979, clause 9 and IEC 804:1985, clause 9.

C.4 Squaring and integrating functions

The squaring and integrating functions shall be tested in accordance with the procedures of IEC 804:1985, clause 9.

Annex D
(informative)

Time-weighting characteristics and tolerances: S and F

The time-weighting characteristics S and F given in IEC 651, table VIII may not be adequate to measure impulsive sounds required by this International Standard. It is recommended that instruments meeting the requirements of table D.1 be used until such time as the current requirements of IEC 651 are replaced with expanded requirements. The maximum levels L in table D.1 are calculated with the equation:

$$L = 10 \lg(1 - e^{t/\tau}) \text{ dB} \qquad \text{... (D.1)}$$

where τ is the time-weighting time constant, which is 0,125 s for time-weighting F and 1,0 s for time-weighting S.

NOTE — If the rise time characteristic of weighting I is used, then equation (D.1) with τ equal to 0,035 s may be used to calculate testing levels.

Table D.1 — Response to a tone burst referred to the response to a continuous signal and corresponding tolerances

Tone burst duration ms	**Maximum level of a tone burst minus the level of a steady tone having the same amplitude** dB	**Tolerance type 1** dB	**Tolerance type 2** dB
125 ms, (F) time constant			
200	− 1,0	± 1	± 1
100	− 2,6	± 1	± 1
10	− 11,1	± 1	± 2
5	− 14,1	± 1	± 2
1	− 21,0	± 2	−
0,5	− 24,0	± 2	−
0,25	− 27,0	± 2	−
1000 ms, (S) time constant			
500	− 4,1	± 1	± 1
100	− 10,2	± 1	± 2
50	− 13,1	± 1	± 2
10	− 20	± 1	± 2
1	− 30	± 2	−

Annex E
(informative)

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