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Acoustics — Determination of occupational noise exposure and estimation of noise-induced hearing impairment

Acoustique — Détermination de l'exposition au bruit en milieu professionnel et estimation du dommage auditif induit par le bruit

Reference number
ISO 1999 : 1990 (E)

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 approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 1999 was prepared by Technical Committee ISO/TC 43, *Acoustics.*

This second edition cancels and replaces the first edition (ISO 1999 : 1975), of which it constitutes a technical revision.

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

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Introduction

This International Standard presents, in statistical terms, the relationship between noise exposures and the "noise-induced permanent threshold shift" (NIPTS) in people of various ages. It provides procedures for estimating the hearing impairment due to noise exposure of populations free from auditory impairment other than that due to noise (with allowance for the effects of age) or of unscreened populations whose hearing capability has been measured or estimated. (NIPTS is treated here as an additive term independent of other components of hearing threshold levels. It is usually zero in the absence of noise exposure, and, for any given noise exposure, it has a range of positive values representing the variability of noise-damage susceptibility between individuals of a population.)

Persons regularly exposed to noise can develop hearing loss of varying severity. Due to this hearing loss their understanding of speech, perception of everyday acoustic signals or appreciation of music may be impaired. With the exception of exposure to blast, high-impulse noise and extremely high levels of steady noise, permanent impairment of the hearing organ takes time and is progressive over months, years or decades of exposure. NIPTS is usually preceded by a reversible temporary effect on hearing, called noise-induced "temporary threshold shift" (TTS). The severity of TTS and recovery from it depend upon exposure level and time. For a single individual, it is not possible to determine precisely which changes in hearing threshold level are caused by noise and which changes are caused by other factors, although, in doubtful individual cases, the data in this International Standard might provide an additional means for estimating the most probable causes in audiological diagnosis. However, for a large population exposed to a specific noise, changes in the statistical distributions of hearing threshold levels can be determined. Parameters such as the mean NIPTS, the median NIPTS, etc., can be used to describe differences in hearing threshold levels between two populations that are similar in all relevant respects except that one population has had a well defined (usually occupational) noise exposure. Throughout this International Standard, the term "NIPTS" is applied to changes in the noise-induced permanent threshold shift of statistical distributions of groups of people; it is not to be applied to individuals.

This International Standard can be applied to calculation of the risk of sustaining hearing handicap due to regular occupational noise exposure or due to any daily repeated noise exposure. In some countries hearing handicap caused by occupational noise exposure can have legal consequences with respect to responsibility and compensation. The hearing threshold level at the various frequencies, at which a hearing handicap is deemed to exist ("fence"), depends not only on the impairment *per se*, but frequently on legal definitions and interpretations based on social and economic considerations. In addition, the definition of a hearing handicap depends on the quality of speech intelligibility desired, the average level of background noise and, with respect to the relative importance of the various frequencies, perhaps even on the language. Consequently, this International Standard does not stipulate (in contrast to the first edition of ISO 1999) a specific formula for assessment of the risk of handicap, but specifies uniform methods for the prediction of hearing impairment, which can be used for the assessment of handicap according to the formula desired or stipulated in a specific country. The results obtained by this International Standard may also be used for estimating the permanent effects of noise on the perception of everyday acoustic signals, the appreciation of music or the effect of one specific frequency not necessarily stipulated by a hearing handicap formula.

Since noise-induced hearing impairment is the result not only of occupational noise exposure but of the total noise exposure of the population, it may be important to take the non-occupational exposure of individuals (during commuting to and from their jobs, at home and during recreational activities) into account. Only if this non-occupational exposure is negligible compared with the occupational exposure does this International Standard allow prediction of the occurrence of hearing impairment due to occupational noise exposure. Otherwise, it should be used to calculate the hearing impairment to be expected from the combined (occupational plus non-occupational) total daily noise exposure. The contribution of the occupational noise exposure to the total hearing impairment can then be estimated, if desired.

The selection of maximum tolerable or maximum permissible noise exposures, and protection requirements as well as the selection of specific formulae for handicap risk assessment or compensation purposes, require consideration of ethical, social, economic and political factors not amenable to international standardization. Individual countries differ in their interpretation of these factors and these factors are therefore considered outside the scope of this International Standard.

For reasons given above this International Standard by itself does not comprise a complete guide for risk assessment and protection requirements, and for practical use it has to be complemented by national standards or codes of practice delineating the factors which are here left open.

Acoustics — Determination of occupational noise exposure and estimation of noise-induced hearing impairment

1 Scope

This International Standard specifies a method for calculating the expected noise-induced permanent threshold shift in the hearing threshold levels of adult populations due to various levels and durations of noise exposure; it provides the basis for calculating hearing handicap according to various formulae when the hearing threshold levels at commonly measured audiometric frequencies, or combinations of such frequencies, exceed a certain value.

NOTE 1 — This International Standard does not specify frequencies, frequency combinations or weighted combinations to be used for the evaluation of hearing handicap; nor does it specify a hearing threshold level ("fence") which must be exceeded for hearing handicap to exist. Quantitative selection of these parameters is left to the user. All sound pressure levels stated in this International Standard do not consider the effect of hearing protectors which would reduce the levels effective at the ear.

The measure of exposure to noise for a population at risk is the averaged A-weighted sound exposure (time-integrated squared sound pressure), $E_{A,T}$, and the related equivalent continuous A-weighted sound pressure level, $L_{Aeq,T}$, over an average working day (assumed to be of 8 h duration), for a given number of years of exposure. This International Standard applies to audio frequency (less than approximately 10 kHz) noise which is steady, intermittent, fluctuating, irregular or impulsive in character. Use of this International Standard for instantaneous sound pressures exceeding 200 Pa (140 dB relative to 20 μPa) and for higher sound pressures should be recognized as extrapolation.

For the assessment of hearing impairment due to exposure to noise, formulae are presented to calculate the NIPTS for audiometric frequencies from 0,5 kHz to 6 kHz for 8 h per day daily A-weighted sound exposure of 364 $Pa^2 \cdot s$ to $1{,}15 \times 10^5$ $Pa^2 \cdot s$ (equivalent continuous A-weighted sound pressure level for a normal 8 h working day from 75 dB to 100 dB), and periods of exposure lasting from 0 to 40 years. Extrapolations to higher levels are not supported by quantitative data. The median values of NIPTS as well as the statistical distribution above and below the median value from the 0,05 to the 0,95 fractile are specified. The NIPTS data are the same for male and female populations.

NOTES

2 Although the NIPTS data are based on data assumed to stem from primarily occupationally noise-exposed populations, they may be used, with some caution, for estimating the effects of comparable non-occupational and combined exposures. (The length of the working day should be stated.)

3 The prediction method presented is based primarily on data collected with essentially broad-band steady non-tonal noise. The application of the data base to tonal or impulsive/impact noise represents the best available extrapolation. Some users may, however, wish to consider tonal noise and/or impulsive/impact noise about as harmful as a steady non-tonal noise that is approximately 5 dB higher in level.

To calculate hearing threshold levels and the risk of acquiring hearing impairment or handicap due to noise exposure, the threshold of hearing of a non-noise-exposed population of comparable age has to be known. Since different criteria can be applied to the selection of this population, this International Standard allows for two possibilities presented by two different data bases :

a) an otologically normal population, that is, "highly screened" (see ISO 7029);

b) any other population selected by the user of the International Standard as being appropriate.

NOTE 4 All data and procedures presented in this International Standard are based on deliberate simplifications of experimental data where the daily sound exposure duration did not exceed 12 h. The resulting approximations restrict the validity to the stated ranges of the variables, fractiles, sound exposure levels and frequency ranges.

This International Standard is based on statistical data and therefore shall not be used to predict or assess the hearing impairment or hearing handicap of individual persons.

Annex A gives the procedure for calculating the age-related hearing threshold levels for an otologically normal population ("highly screened") in accordance with ISO 7029.

Annex B gives as an example of the second data base the procedure for calculating the age-related threshold levels for an unscreened population of a typical industrialized society.

Annex C gives an example of selected values of the hearing threshold levels of a specific unscreened population, which, when used with the procedures of this International Standard, results in approximately the same risk of hearing handicap as the one predicted by the first edition of ISO 1999.

Annex D describes an example of hearing risk assessment using this International Standard.

Annex E presents tables with examples of NIPTS as a function of exposure time (10, 20, 30 and 40 years) and daily A-weighted sound exposure ($3{,}64 \times 10^3$, $1{,}15 \times 10^4$, $3{,}64 \times 10^4$ and $1{,}15 \times 10^5$ $Pa^2 \cdot s$, or equivalent continuous A-weighted sound pressure level for nominal 8 h working day of 85, 90, 95 and 100 dB) for six frequencies (0,5, 1, 2, 3, 4 and 6 kHz) and three fractiles (0,1, 0,5 and 0,9).

A bibliography is given in annex F.

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.

ISO 389 : 1985, *Acoustics — Standard reference zero for the calibration of pure tone air conduction audiometers.*

ISO 1683 : 1983, *Acoustics — Preferred reference quantities for acoustic levels.*

ISO 1996-1 : 1982, *Acoustics — Description and measurement of environmental noise — Part 1 : Basic quantities and procedures.*

ISO 1996-2 : 1987, *Acoustics — Description and measurement of environmental noise — Part 2: Acquisition of data pertinent to land use.*

ISO 2204 : 1979, *Acoustics — Guide to International Standards on the measurement of airborne acoustical noise and evaluation of its effects on human beings.*

ISO 7029 : 1984, *Acoustics — Threshold of hearing by air conduction as a function of age and sex for otologically normal persons.*

IEC 651 : 1979, *Sound level meters.*

IEC 804 : 1985, *Integrating-averaging sound level meters.*

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 sound pressure level, L_p : The level, in decibels, given by the equation

$$L_p = 10 \lg (p/p_o)^2$$

where p is the sound pressure, in pascals. The reference sound pressure, p_o, is 20 µPa, in accordance with ISO 1683.

3.2 A-weighted sound pressure level, L_{pA}: The sound pressure level, in decibels, determined by using frequency-weighting A (see IEC 651), from the equation

$$L_{pA} = 10 \lg (p_A/p_o)^2$$

where p_A is the A-weighted sound pressure, in pascals.

3.3 A-weighted sound exposure, $E_{A,T}$: The time integral of the squared A-weighted sound pressure over a specified time period, T, or event, expressed in pascal squared seconds ($Pa^2 \cdot s$). A-weighted sound exposure is given by the equation

$$E_{A,T} = \int_{t_1}^{t_2} p_A^2(t)\, dt$$

where $p_A(t)$ is the instantaneous A-weighted sound pressure of the sound signal integrated over a time period T starting at t_1 and ending at t_2.

The period, T, measured in seconds, is usually chosen so as to cover a whole day of occupational exposure to noise (usually 8 h, 28 800 s) or a longer period that is to be specified, for example a working week.

NOTES

1 The sound exposure level, $L_{EA,T}$, in decibels, is

$$L_{EA,T} = 10 \lg (E_{A,T}/E_o)$$

with $E_o = 4 \times 10^{-10}$ $Pa^2 \cdot s$, as given in ISO 1996-1 and IEC 804.

2 The noise exposure level normalized to a nominal 8 h working day, $L_{EX,8h}$, is obtained with $E_o = 1{,}15 \times 10^{-5}$ $Pa^2 \cdot s$ and is 44,5 dB less than $L_{EA,T}$ (see 3.6).

3.4 daily A-weighted sound exposure, $E_{A,D}$: The total A-weighted sound exposure sustained in a single 24 h day, expressed in pascal squared seconds ($Pa^2 \cdot s$).

NOTE — If it is desired to take into account significant non-occupational noise exposure, the total value of A-weighted sound exposure is obtained by summing the occupational component and a corresponding component from the non-occupational exposure. See the Introduction.

3.5 equivalent continuous A-weighted sound pressure level, $L_{Aeq,T}$: The level, in decibels, given by the equation

$$L_{Aeq,T} = 10 \lg \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{p_A^2(t)}{p_o^2}\, dt \right]$$

where $t_2 - t_1$ is the period T over which the average is taken starting at t_1 and ending at t_2.

NOTES

1 The period, $t_2 - t_1$, used for direct measurement or calculation of $L_{Aeq,T}$, should be chosen to give results representative of the whole period.

2 For continuous noise, unvarying in level, L_{Aeq} is numerically equal to L_{pA}.

3.6 noise exposure level normalized to a nominal 8 h working day, $L_{EX,8h}$: The level, in decibels, given by the equation

$$L_{EX,8h} = L_{Aeq,T_e} + 10 \lg (T_e/T_o)$$

where

T_e is the effective duration of the working day;

T_o is the reference duration (= 8 h).