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Acoustics — Estimation of noise-induced hearing loss

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National foreword

This British Standard is the UK implementation of ISO 1999:2013.

The UK participation in its preparation was entrusted to Technical Committee EH/1/1, Hearing.

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

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Acoustics — Estimation of noise-induced hearing loss

Acoustique — Estimation de la perte auditive induite par le bruit

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Foreword

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

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

The committee responsible for this document is ISO/TC 43, *Acoustics*.

This third edition cancels and replaces the second edition (ISO 1999:1990), of which it constitutes a minor revision.

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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 loss 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. 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 duration. 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 and the median NIPTS, 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 the calculation of the risk of sustaining hearing loss due to regular occupational noise exposure or due to any daily repeated noise exposure. In some countries, hearing loss 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 impairment is deemed to exist (fence), depends not only on the hearing loss per se, but frequently on legal definitions and interpretations based on social and economic considerations. In addition, the definition of a hearing impairment depends on the quality of speech recognition 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 impairment, but specifies uniform methods for the prediction of hearing loss, which can be used for the assessment of impairment 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 impairment formula.

Since noise-induced hearing loss is the result not only of occupational noise exposure but also 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 loss due to occupational noise exposure. Otherwise, it should be used to calculate the hearing loss 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 loss 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 impairment 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.

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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.

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INTERNATIONAL STANDARD ISO 1999:2013(E)

Acoustics — Estimation of noise-induced hearing loss

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 disability 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 disability; nor does it specify a hearing threshold level (fence) which it is necessary to exceed for hearing disability 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 effective exposure levels and modify the spectrum at the ear.

The measure of exposure to noise for a population at risk is the noise exposure level normalized to a nominal 8 h working day, $L_{EX,8h}$, for a given number of years of exposure. This International Standard applies to noise at frequencies less than approximately 10 kHz which is steady, intermittent, fluctuating, irregular. Use of this International Standard for sound pressures exceeding 200 Pa (140 dB relative to 20 μPa) is recognized as extrapolation.

Formulae are presented to calculate the hearing loss, including statistical distribution, at a range of audiometric frequencies due to exposure to noise as a function of level of noise exposure and duration of exposure (in years). The formulae do not distinguish between male and female populations.

NOTE 2 Although the models of hearing loss are based on data assumed to stem primarily from populations exposed to occupational noise, they may be used, with some caution, for estimating the effects of comparable non-occupational and combined exposures.

NOTE 3 The prediction method presented is based primarily on data collected with essentially broadband, steady, non-tonal noise.

To calculate hearing threshold levels and the risk of acquiring hearing loss due to noise exposure, it is necessary to make use of a comparable population. This International Standard contains a definition of a highly screened otologically normal population (in accordance with ISO 7029) and three examples of unscreened populations of three typical industrialized societies. The users of this International Standard may choose a comparable population according to their particular requirements.

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, percentages, sound exposure levels, and frequency ranges.

This International Standard is based on statistical data and therefore cannot be applied to the prediction or assessment of the hearing loss of individual persons except in terms of statistical probabilities.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7029, *Acoustics — Statistical distribution of hearing thresholds as a function of age*

ISO 9612, *Acoustics — Determination of occupational noise exposure — Engineering method*

ISO/TR 25417, *Acoustics — Definitions of basic quantities and terms*

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3 Terms and definitions

For the purposes of this document, the terms and definitions in ISO/TR 25417 and the following apply.

3.1
A-weighted noise exposure level normalized to a nominal 8 h working day
$L_{EX,8h}$
level, in decibels, given by the formula

$$L_{EX,8h} = L_{p\,Aeq,Te} + 10 \lg \left(T_e / T_0\right) \text{ dB}$$

where

$L_{pAeq,Te}$ is the A-weighted equivalent continuous sound pressure level for T_e;

T_e is the effective duration of the working day in hours;

T_0 is the reference duration (T_0 = 8 h).

Note 1 to entry: The quantity "noise exposure level normalized to a nominal 8 h working day" may also be called "daily noise exposure level".

Note 2 to entry: If the exposure averaged over n days is desired, for example if noise exposure levels normalized to a nominal 8 h working day for weekly exposures are considered, the average value of $L_{EX,8h}$, in decibels, over the whole period may be determined from the values of $(L_{EX,8h})_i$ for each day using the following formula:

$$\overline{L_{EX,8h}} = 10 \lg \left[\frac{1}{c} \sum_{i=1}^{n} 10^{0,1(L_{EX,8h})_i} \right] \text{ dB}$$

The value of c is chosen according to the purpose of the averaging process: it will be equal to n if an average value is desired; it will be a conventional fixed number if the exposure is to be normalized to a nominal number of days (for example, when n = 7, c = 5 will lead to a daily noise exposure level normalized to a nominal week of 5 eight-hour working days). For consideration of irregular exposures over an extended time period, see ISO 9612.

3.2
hearing loss
deviation or a change for the worse of the threshold of hearing from normal

Note 1 to entry: The term hearing loss may sometimes only refer to a change.

3.3
hearing disability
effect of hearing loss on activities in daily living

Note 1 to entry: This is sometimes called "activity limitation" (WHO).

3.4
fence
hearing threshold level above which degrees of hearing disability are deemed to exist

3.5
risk of hearing disability
percentage of a population sustaining hearing disability

3.6
risk of hearing disability due to noise
risk of hearing disability in a noise-exposed population minus the risk of hearing disability in a population not exposed to noise but otherwise equivalent to the noise-exposed population

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3.7
hearing threshold level associated with age
HTLA
H
for a specified fraction of a population, the hearing threshold level observed as a function of age without any exposure to occupational noise

Note 1 to entry: HTLA can be directly observed only in the absence of other causes of hearing impairment, for example, pathological conditions or noise exposure.

3.8
noise-induced permanent threshold shift
NIPTS
N
for a specified fraction of a population, the permanent shift, actual or potential, in decibels, of the hearing threshold level estimated to be caused solely by exposure to noise, in the absence of other causes

3.9
hearing threshold level associated with age and noise
HTLAN
H'
permanent hearing threshold level for a specified fraction of a population

Note 1 to entry: Hearing threshold levels (HTL), as defined in ISO 389, are expressed in decibels.

Note 2 to entry: The value HTLAN is a combination of the components associated with noise (NIPTS, see 3.8) and with age (HTLA, see 3.7), as defined in 6.1.

4 Principle

Annex A gives the procedure for calculating the statistical distribution of hearing threshold levels relative to the hearing threshold levels at the age of 18 years as a function of age for an otologically normal population (highly screened) in accordance with ISO 7029.

Annex B gives three examples of the second database representing the statistical distribution of hearing threshold levels as a function of age for unscreened populations of three typical industrialized societies. These databases are derived from three recent studies in different countries and the data differ significantly from those of database B in the previous edition of this International Standard. In two of the examples, the test subjects have not been exposed to hazardous occupational noise but otherwise represent all other factors that may affect hearing, e.g. age, genetic dispositions, non-occupational noise, and ear diseases. The third database concerns a completely unscreened population, as explained in B.3.

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

Annex D presents tables with examples of NIPTS as a function of exposure duration (10 years, 20 years, 30 years, and 40 years) and daily A-weighted sound exposure ($3{,}64 \times 10^3$ Pa^2s, $1{,}15 \times 10^4$ Pa^2s, $3{,}64 \times 10^4$ Pa^2s and $1{,}15x\ 10^5$ Pa^2s or equivalent continuous A-weighted sound pressure level for nominal 8 h working day of 85 dB, 90 dB, 95 dB, and 100 dB) for six frequencies (0,5 kHz, 1 kHz, 2 kHz, 3 kHz, 4 kHz, and 6 kHz) and three percentages (10 %, 50 %, and 90 %).

5 Description and measurement of noise exposure

Methods for the determination of occupational noise exposure are specified in ISO 9612.

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