SLOVENSKI STANDARD
oSIST ISO/DIS 1999:2012

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Akustika - Ugotavljanje izgube sluha zaradi hrupa

Acoustics -- Estimation of noise-induced hearing loss

Acoustique -- Estimation de la perte auditive induite par le bruit

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Acoustics — Estimation of noise-induced hearing loss

Acoustique — Estimation de la perte auditive induite par le bruit

[Revision of second edition (ISO1999:1990)]

ICS 13.140

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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.

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Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

This second edition cancels and replaces the first edition ISO 1999:1990.

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. 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 **l**oss 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 impairment due to regular occupational noise exposure or due to any daily repeated noise exposure. In some countries hearing impairment 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 impairment *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 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 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.

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 — 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 impairment 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 impairment; nor does it specify a hearing threshold level ("fence") which must be exceeded for hearing impairment 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 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, $L_{EX,8h}$), 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 or impulsive in character. Use of this International Standard for sound pressures exceeding 200 Pa (140 dB relative to 20 μPa) 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^2s to 1,15 x 10^5 Pa^2s (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 years 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.

NOTE 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.

NOTE 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 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 of individual persons except in terms of statistical probabilities.

Annex A gives the procedure for calculating the statistical distribution of hearing threshold levels 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 data base representing the statistical distribution of hearing threshold levels as a function of age for unscreened populations of three typical industrialized societies. These data bases are derived from three recent studies in different countries, and the data differ significantly from those of Data base 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, ear diseases. The third data base concerns a completely unscreened population, as explained in Annex 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 time (10 years, 20 years, 30 years and 40 years) and daily A-weighted sound exposure (3,64 x 10^3 Pa^2s, 1,15 x 10^4 Pa^2s, 3,64 x 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 fractiles (0,1, 0,5 and 0,9).

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*

3 Definitions

In addition to the definitions in ISO/TR 25417, for the purposes of this document, the following definitions apply.

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

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

where

$L_{p\mathrm{Aeq},T_e}$ is the equivalent continuous A-weighted sound pressure level

T_e is the effective duration of the working day;

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

NOTE 1 If the effective duration of the working day, T_e, is equal to 8 h, then $L_{EX,8h}$ equals $L_{p\mathrm{Aeq},8h}$. The quantity “noise exposure level normalized to a nominal 8 h working day” may also be called “daily noise exposure level”

NOTE 2 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 equation:

$$\overline{L_{EX,8h}} = 10 \lg \left[\frac{1}{c} \sum_{i=1}^{n} 10^{01(L_{EX,8h})_i} \right] \text{dB}$$

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, c = 5 will lead to a daily noise exposure level normalized to a nominal week of 5 eight-hour working days).

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

NOTE The term hearing loss may sometimes only refer to a change.

3.3
hearing disability
hearing impairment that affects activities in daily living

NOTE 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
fractile of a population sustaining hearing disability (see 6.3)

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

3.7
hearing threshold level associated with age and noise (HTLAN), H'
permanent hearing threshold level, for a specified fraction of a population

NOTE 1 Hearing threshold levels (HTL) as defined in ISO 389 are expressed in decibels

NOTE 2 The value HTLAN is a combination of the components associated with noise (NIPTS, see 3.7) and with age (HTLA, see 3.8) as defined in 5.1.

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 (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 HTLA can be directly observed only in the absence of other causes of hearing impairment; for example, pathological conditions or noise exposure.

4 Description and measurement of noise exposure

Detailed requirements for the correct determination of occupational noise exposure are specified in ISO 9612.

5 Prediction of the effects of noise on hearing threshold

5.1 Statistical distribution of hearing threshold levels of a noise-exposed population

The hearing threshold level, in decibels, associated with age and noise (HTLAN), H', of a noise-exposed population is calculated, for the purposes of this International Standard, by using the following empirical formula:

$$H' = H + N - \frac{H \times N}{120} \qquad (1)$$

where

H is the numerical value of the hearing threshold level, expressed in decibels, associated with age (HTLA);

N is the numerical value of the actual or potential noise-induced permanent threshold shift (NIPTS), expressed in decibels;

The formula is applicable only to corresponding fractile values of H', H and N.

NOTE The additive relationship is an approximation to the biological events and is considered accurate enough for the purposes of this International Standard. Frequently, the term $\left(N - \frac{H \times N}{120}\right)$ is called the actual NIPTS.

The term $\frac{H \times N}{120}$ starts to modify the result significantly only when $H + N$ is more than approximately 40 dB.

5.2 Data bases for hearing threshold levels associated with age (HTLA)

5.2.1 General

The hearing of a non-noise-exposed population as a function of age depends on the degree to which other factors besides aging are inadvertently included; diseases, history of ototoxic drugs and unknown noise exposure of occupational or non-occupational origin may modify the HTLA. Different approaches to screening such data have been used, and the selection of the most appropriate data base depends on the purpose of the application (see 5.2.4). This International Standard permits two data bases (data bases A and B) to be used for HTLA in 5.1. Data base A is fully specified, whereas data base B is at the discretion of the user. Three examples of data base B are presented.

NOTE The data bases presented in annexes A and B are from populations of European and North American countries. These populations may or may not be appropriate for the populations of other geographical areas. Even if there are no differences in natural aging between different ethnic populations, differences in life style, non-occupational noise exposure, incidence of disease, and ototoxic drugs are nevertheless liable to occur.

5.2.2 Data base A

Data base A derives from otologically normal persons, i.e. persons in a normal state of health who are free from all signs or symptoms of ear disease and from obstructing wax in the ear canals and who have no history of undue exposure to noise. The statistical distributions of the thresholds of such "highly screened" populations have been standardized in ISO 7029 separately for male and female populations. Formuale for calculating data base A are specified in A.1. A table with selected values is given in A.2.