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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
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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 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

$$L_p = 10 \lg (p/p_0)^2$$

where p is the sound pressure, in pascals. The reference sound pressure, p_0, 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

$$L_{pA} = 10 \lg (p_A/p_0)^2$$

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

$$L_{EA,T} = 10 \lg (E_{A,T}/E_0)$$

with $E_0 = 4 \times 10^{-10}$ $Pa^2 \cdot s$, 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 $E_0 = 1{,}15 \times 10^{-5}$ $Pa^2 \cdot s$ 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

$$L_{Aeq,T} = 10 \lg \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{p_A^2(t)}{p_0^2} dt \right]$$

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

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

where

T_e is the effective duration of the working day;

T_0 is the reference duration (= 8 h).

If the effective duration of the working day, T_e, does not exceed 8 h, $L_{EX,\,8h}$ is numerically equal to $L_{Aeq,\,8h}$.

NOTES

1 The noise exposure level normalized to a nominal 8 h working day, $L_{EX,\,8h}$, in decibels, may be calculated from the A-weighted sound exposure, $E_{A,\,T_e}$, in pascal squared seconds (Pa²·s), using the following formula:

$$L_{EX,\,8h} = 10 \lg \frac{E_{A,\,T_e}}{1{,}15 \times 10^{-5}}$$

Selected values of sound exposures with corresponding values of noise exposure levels normalized to a nominal 8 h working day are given for illustration in table 1.

Table 1 — A-weighted sound exposures and corresponding noise exposure levels normalized to a nominal 8 h working day

$E_{A,\,T_e}$ Pa²·s	$L_{EX,\,8h}$ dB
0,364 × 10³	75
0,458 × 10³	76
0,576 × 10³	77
0,726 × 10³	78
0,913 × 10³	79
1,15 × 10³	80
1,45 × 10³	81
1,82 × 10³	82
2,29 × 10³	83
2,89 × 10³	84
3,64 × 10³	85
4,58 × 10³	86
5,76 × 10³	87
7,26 × 10³	88
9,13 × 10³	89
11,5 × 10³	90
14,5 × 10³	91
18,2 × 10³	92
22,9 × 10³	93
28,9 × 10³	94
36,4 × 10³	95
45,8 × 10³	96
57,6 × 10³	97
72,6 × 10³	98
91,3 × 10³	99
115 × 10³	100

2 If the exposures averaged over n days are 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:

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

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

3.7 hearing impairment : A deviation or a change for the worse of the threshold of hearing from normal.

NOTE — Impairment is usually understood to refer to structure or function. Throughout this International Standard only impairment of function is considered.

3.8 hearing handicap : The disadvantage imposed by hearing impairment sufficient to affect one's personal efficiency in the activities of daily living, usually expressed in terms of understanding of conversational speech in low levels of background noise. A numerical representation of hearing handicap is given by a combination of hearing threshold levels as described in 6.2.

3.9 fence: A hearing threshold level above which degrees of hearing handicap (or disability) are deemed to exist.

3.10 risk of hearing handicap: The fractile of a population sustaining hearing handicap (see 6.3).

3.10.1 risk of hearing handicap due to noise: The risk of hearing handicap in a noise-exposed population minus the risk of hearing handicap in a population not exposed to noise, but otherwise equivalent to the noise-exposed population.

3.11 hearing threshold level associated with age and noise (HTLAN), H': The permanent threshold of hearing, in decibels, of a population [as defined as hearing threshold level (HTL) in ISO 389].

The value HTLAN is a combination of the components associated with noise (NIPTS, see 3.12) and with age (HTLA, see 3.13) as defined in 5.1.

3.12 noise-induced permanent threshold shift (NIPTS), N : 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.

3.13 hearing threshold level associated with age (HTLA), H : The hearing threshold level, in decibels, observed solely in association with age without any influence of noise exposure.

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

3.14 impulsive noise: Although impulsive noise can be defined in different ways (see ISO 2204 and ISO 1996-2), for the purposes of this International Standard all non-steady noises in industry usually characterized as impact or impulse noise are to be included in a measurement of sound exposure (see notes in clause 1).

4 Description and measurement of exposure to noise

4.1 General

To estimate hearing impairment and risk of hearing handicap as a result of exposure to noise, the average A-weighted sound exposure, $E_{A,8h}$ and/or the noise exposure level normalized to a nominal 8 h working day, $L_{EX,\,8h}$, shall be either measured directly by sound exposure meters or integrating sound level meters or calculated from sound pressure measurements and exposure time. Such measurements may be made with instruments that are either stationary or attached to the person.

The measurement locations and the duration of the measurements shall be chosen so as to represent the exposure to noise experienced during a typical day by the population at risk.

4.2 Instrumentation

4.2.1 General

For direct measurement of equivalent continuous A-weighted sound pressure levels, integrating-averaging sound level meters shall comply with IEC 804, type 2 or better.

Until an International Standard concerning instrumentation for measuring sound exposure is published, suitable instruments are permitted provided they fulfil the following minimum requirements :

- the frequency weighting of the measurement instrumentation shall comply with IEC 651;
- the squared A-weighted sound pressure shall be integrated over suitable periods of time, for the indication of A-weighted sound exposure, $E_{A,T}$ and equivalent continuous A-weighted sound pressure level, $L_{Aeq,T}$;
- special care shall be taken to ensure that the dynamic range is large enough for the applications and that the inherent electrical noise and the overload capacity of the instrument are suitable.

4.2.2 Recording of data

If data are stored on tape as an essential step of the measurement procedure, potential errors caused by the process of storing and replay shall be taken into account when analysing the data.

4.2.3 Calibrating and checking

All equipment shall be calibrated, and the configuration for calibration and checking shall be in accordance with the manufacturer's instructions.

NOTE — A comprehensive recalibration at certain time intervals (for example, annually) may be prescribed by authorities responsible for the use of the results of the measurements.

A field check shall be made by the user at least before and after each series of measurements. An electric check of amplifiers, recorders and indicators shall be made as well as an acoustic check of the sensitivity of the microphone and/or the total system.

4.3 Microphone positions

The measurement of sound pressure to determine the A-weighted sound exposure and/or the equivalent continuous A-weighted sound pressure level shall be made with the microphone located at the position(s) normally occupied by the head of the person concerned, the person being absent.

If it is necessary for the person to be present or for the person to move around, the microphone should be located 0,10 m ± 0,01 m from the entrance of the external ear canal of the ear receiving the higher value of the A-weighted sound exposure or the equivalent continuous A-weighted sound pressure level.

The exact positions at which the measurements are made shall be reported.

4.4 Measurement

4.4.1 General

Pertinent details of the measuring instrumentation, measurement procedure and conditions prevailing during the measurements shall be carefully recorded and kept for reference purposes. When reporting the measurement result, an estimation of the overall measurement uncertainty shall be stated taking into account the influence of factors such as

- measuring instrumentation;
- microphone positions;
- number of measurements;
- time and spatial variation of the noise source.

4.4.2 Daily exposure to noise over an extended time period

The daily A-weighted sound exposure or the noise exposure level shall be determined in accordance with 4.4.3, 4.4.4 or 4.4.5 for a sufficient number of days and for the individuals under consideration to allow the determination of the average exposure to noise for the years or decades under consideration with an overall uncertainty appropriate to the particular noise problem.

The average daily exposure to noise over the total number of days for an individual or a group of individuals shall be calculated in accordance with 3.6, using table 1.

When the noise is not the same from day to day, this International Standard is primarily applicable when the daily equivalent continuous A-weighted sound pressure level on the worst day does not exceed, by more than 10 dB, the equivalent continuous A-weighted sound pressure level averaged over a longer period (not exceeding 1 year).

NOTE — For exposure to noise too irregular for this International Standard to be applied, monitoring audiometry is recommended.

4.4.3 Direct measurement of daily exposure to noise

The direct determination of the daily exposure shall be made by instrumentation which provides an indication of the A-weighted sound exposure or the equivalent continuous A-weighted sound pressure level. Such instrumentation integrates the fluctuations of the noise produced by a time-varying noise source or by movement of the person from place to place. The fluctuations may be spread over a wide range of levels and/or be of irregular time characteristic. The fluctuations may also include noises of impulsive character.

4.4.4 Indirect measurement of daily exposure to noise

4.4.4.1 General

For indirect measurement of exposure to noise, sound pressure levels shall be measured with a sound level meter or equivalent recording equipment. The exposure time for each clearly distinguishable level range shall be measured separately.

NOTE — Integrating sound level meters are preferred. If conventional sound level meters are used, time-weighting characteristic F (fast) is recommended and time-weighting characteristic I (impulse) is not recommended.

The A-weighted sound exposure and the noise exposure level normalized to a nominal 8 h working day shall then be determined in accordance with the procedures outlined in 4.4.4.3. This method is also applicable for theoretical predictions.

4.4.4.2 Exposure to steady noise

If the noise is such that the fluctuations in level are small (see the note) for the whole period for which the equivalent continuous A-weighted sound pressure level is being determined, the arithmetic average of the indicated sound pressure level is numerically equal to the equivalent continuous sound pressure level.

NOTE — The noise may be deemed steady if the total range of indicated sound pressure levels lies within a range of 5 dB with time-weighting characteristic S (slow).

4.4.4.3 Exposure to steady noise with stepwise variations in level

If the noise is steady but occurs at a number of clearly distinguishable levels, the separate levels shall be measured in accordance with 4.4.4.2 together with the corresponding durations of the different level steps. The total A-weighted sound exposure, $E_{A,T}$, shall be calculated, in pascal squared seconds ($Pa^2 \cdot s$), by using the equation

$$E_{A,T} = \sum_{i=1}^{n} p_0^2 \left[T_i \times 10^{0,1 L_{Aeq,T_i}} \right]$$

where

L_{Aeq,T_i} is the equivalent continuous A-weighted sound pressure level, in decibels, occurring over the time interval T_i;

n is the total number of clearly distinguishable levels.

The equivalent continuous A-weighted sound pressure level, $L_{Aeq,T}$, in decibels, shall be calculated from $E_{A,T}$ or by using the following equation :

$$L_{Aeq,T} = 10 \lg \left[\frac{1}{T} \sum_{i=1}^{n} \left(T_i \times 10^{0,1 L_{Aeq,T_i}} \right) \right]$$

where

L_{Aeq,T_i} is the equivalent continuous A-weighted sound pressure level, in decibels, averaged over time interval T_i;

$$T = \sum_{i=1}^{n} T_i$$

The noise exposure level is then determined in accordance with 3.6.

4.4.5 Measurement of daily noise exposure using sampling methods and statistical distribution

4.4.5.1 General

An approximation to the result of the direct method by using a number of samples taken at different times depends on the number of uncorrelated samples. The duration of the sample measurement and the sampling rate shall be chosen to provide sufficient accuracy for the estimate of the equivalent continuous A-weighted sound pressure level.

4.4.5.2 Sampling method

The indication of a conventional sound level meter is read either visually or automatically at sampling intervals Δt [sampling rate $(1/\Delta t)$] over the measurement duration T_{meas}. The equivalent continuous A-weighted sound pressure level, $L_{Aeq,T_{meas}}$, is calculated, in decibels, by using the equation

$$L_{Aeq,T_{meas}} = 10 \lg \left[\frac{1}{n} \sum_{i=1}^{n} \left(10^{0,1 L_{pAi}} \right) \right]$$

where

L_{pAi} is the A-weighted sound pressure level, in decibels, for sample i;

n is the total number of samples collected within T_{meas}. The duration of the time intervals may be constant or may vary at random.

4.4.5.3 Use of the statistical distribution

The indication of a conventional sound level meter, time-weighting characteristic F (fast), is read either visually or automatically at sampling intervals Δt over the measurement duration T_{meas}. The measured values L_{pAi} shall be grouped in classes having a width of 5, 2,5 or 1 dB or any width less than 1 dB.

NOTE — The width of the classes should be not greater than approximately one fifth of the span of the measured sound pressure levels.

The equivalent continuous A-weighted sound pressure level, $L_{Aeq,T_{meas}}$, in decibels, shall be calculated by using the following equation :

$$L_{Aeq,T_{meas}} = 10 \lg \left[\frac{1}{n} \sum_{j=1}^{M} \left(n_j \times 10^{0,1 L_{pAj}} \right) \right]$$

where

L_{pAj} is the mid-level of class j, in decibels;

M is the total number of classes;

n_j is the number of samples in class j;

n is equal to $\frac{T_{meas}}{\Delta t}$ and to the total number of samples.

5 Prediction of the effects of noise on hearing threshold

5.1 Hearing threshold level 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:

$$H' = H + N - \frac{HN}{120}$$

where

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

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

The equation 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 $\left(N - \frac{HN}{120}\right)$ is called the actual NIPTS.

The term $\frac{HN}{120}$ 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)

The hearing of a non-noise-exposed population as a function of age depends on the degree to which other factors besides natural 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 5.2.3). 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. An example of data base B is presented.

5.2.1 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. Equations for calculating data base A are specified in clause A.1. A table with selected values is given in clause A.2.

5.2.2 Data base B

For data base B, a set of data collected on a control population not occupationally exposed to noise of the country under consideration is recommended.

A separate HTLA data base for both men and women is required unless it can be shown that there are no substantial sex differences. It is essential that the sample size be large enough to allow calculations of a valid statistical distribution.

A data base has, therefore, to be compiled by the user of this International Standard based on selection criteria the user considers appropriate. For instance, the average HTLA of both ears or the better ear alone can be taken as the basis for data base B.

NOTE 1 — It is emphasized that for practical situations the accuracy of the prediction of the hearing threshold level of a noise-exposed population will largely be a function of the accuracy of the selected data base for HTLA. Since audiometric measurement techniques affect threshold measurements, the same measurement technique should be used in the establishment of a specific HTLA data base as might be used to obtain or verify the threshold of hearing of the noise-exposed population.

An example of data base B is presented in annex B for an unscreened population (males and females). This example is considered representative of a data base B for an industrialized country.

NOTE 2 — 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.

5.2.3 Choice of data base

Whether data base A or B is the more appropriate (or whether the numerical example for data base B in annex B is suitable) depends on what question is to be answered. For example, if the amount of compensation that could be due to a population of noise-exposed workers is to be estimated, and otological irregularities and non-occupational noise exposure are not considered in compensation cases, unscreened populations will form the more appropriate data bases.

NOTE — A special example for partial data base B is given in annex C. It lists selected hearing threshold level associated with age (HTLA) data which, when used with the procedures of this International Standard, result in approximately the same estimated risk of hearing handicap as the one predicted by the first edition of ISO 1999. These data are presented only to facilitate transition to the more accurate data in this International Standard (the second edition).

5.3 Calculation of noise-induced permanent threshold shift, N

5.3.1 Calculation of $N_{0,50}$

The median potential noise-induced permanent threshold shift (NIPTS) values to be used in 5.1 are functions of audiometric frequency, the exposure time, the ratio Θ/Θ_0 and the noise exposure level normalized to a nominal 8 h working day, $L_{EX, 8h}$ (see 3.6), averaged over the exposure time Θ. For exposure times between 10 and 40 years the median potential NIPTS values, $N_{0,50}$, in decibels, are given for both sexes by the equation

$$N_{0,50} = [u + v \lg (\Theta/\Theta_0)] (L_{EX, 8h} - L_0)^2$$

where

L_0 is a cut-off sound pressure level defined as a function of frequency in table 2;

Θ is the exposure time, in years;

Θ_0 is one year;

u and v are given as a function of frequency in table 2.

The equation applies for $L_{EX, 8h}$ greater than L_0. In cases where $L_{EX, 8h}$ is less than L_0, it shall be deemed to be equal to L_0 so that $N_{0,50}$ is zero.

For exposure times less than 10 years, N shall be extrapolated from the value of $N_{0,50}$ for 10 years using the equation

$$N_{0,50; \Theta < 10} = \frac{\lg (\Theta + 1)}{\lg (11)} N_{0,50; \Theta = 10}$$

Table 2 — Values of u, v and L_0 used to determine the NIPTS for the median value of the population, $N_{0,50}$

Frequency Hz	u	v	L_0 dB
500	−0,033	0,110	93
1 000	−0,020	0,070	89
2 000	−0,045	0,066	80
3 000	+0,012	0,037	77
4 000	+0,025	0,025	75
6 000	+0,019	0,024	77

5.3.2 Statistical distribution of N

For the purposes of this International Standard, the statistical distribution of N is approximated by two different halves of two normal (Gaussian) distributions. The upper half for the fractile with hearing worse than the median lies above the median value $N_{0,50}$ and is characterized by the parameter d_u; the lower half lies below the median and has the smaller dispersion characterized by the parameter d_l. For a fractile of Q of the population such that $0,05 < Q < 0,50$ the NIPTS is given by the equation

$$N_Q = N_{0,50} + k d_u$$

For a fractile of Q of the population such that $0,50 < Q < 0,95$ the NIPTS is given by the equation

$$N_Q = N_{0,50} - k d_l$$

The values for the multiplier k corresponding to the normal (Gaussian) distribution are given in 5.3.2.1; d_u and d_l shall be calculated in accordance with 5.3.2.2.

NOTE — Tails of the statistical distributions for $0 < Q < 0,05$ and for $0,95 < Q < 1$ are unreliable and should not be estimated since few experimental data exist to validate these ranges.

5.3.2.1 Values of k

Values of the multiplier k are given in table 3 in intervals of 0,05 for Q.

Table 3 — Values of the multiplier k

Q		k
0,05	0,95	1,645
0,10	0,90	1,282
0,15	0,85	1,036
0,20	0,80	0,842
0,25	0,75	0,675
0,30	0,70	0,524
0,35	0,65	0,385
0,40	0,60	0,253
0,45	0,55	0,126
0,50		0
NOTE — Interpolations between the values presented can be obtained from ISO 7029.		

5.3.2.2 Parameters d_u and d_l

The parameters d_u and d_l to be substituted in the equations are calculated as follows :

$$d_u = [X_u + Y_u \lg (\Theta/\Theta_0)] (L_{EX, 8h} - L_0)^2$$

$$d_l = [X_l + Y_l \lg (\Theta/\Theta_0)] (L_{EX, 8h} - L_0)^2$$

where

X_u, Y_u and X_l, Y_l are given as a function of audiometric frequency in table 4;

$L_{EX, 8h}$ is the noise exposure level normalized to a nominal 8 h working day (see 3.6);

Θ is the exposure time, in years;

Θ_0 is one year;

L_0 is the cut-off level (see 5.3.2) given in table 2 for $L_{EX, 8h}$ greater than L_0. Should $L_{EX, 8h}$ be less than L_0, it shall be deemed equal to L_0.

Table 4 — Values of X_u, Y_u and X_l, Y_l used to determine respectively the parameters d_u and d_l characterizing the upper and lower parts of the statistical distribution of NIPTS ($N_{0,05} < N < N_{0,95}$)

Frequency Hz	X_u	Y_u	X_l	Y_l
500	0,044	0,016	0,033	0,002
1 000	0,022	0,016	0,020	0,000
2 000	0,031	−0,002	0,016	0,000
3 000	0,007	0,016	0,029	−0,010
4 000	0,005	0,009	0,016	−0,002
6 000	0,013	0,008	0,028	−0,007

6 Assessment of noise-induced hearing impairment and handicap

6.1 Hearing impairment

Potential hearing impairment due to occupational exposure to noise is directly assessed by the noise-induced permanent threshold shift calculated in accordance with 5.3 for the exposure conditions and populations under consideration. The NIPTS can be

a) considered separately for each frequency of interest;

b) added for a certain number of frequencies to result in a "total" threshold shift;

c) averaged for a number of selected frequencies usually representing the main speech intelligibility frequency range (see note in 6.2).

6.2 Hearing handicap (or disability)

For the calculation of hearing handicap, a combination of hearing threshold levels at specified frequencies shall be used. The hearing threshold levels for the populations, their fractiles and exposure conditions of interest shall be calculated in accordance with clause 5.

NOTE — Commonly used or proposed equations for the assessment of hearing handicap for conversational speech use one of the following frequency combinations (in kHz) for averaging hearing threshold levels:

a) average of HTL at 0,5, 1 and 2 kHz;

b) average of HTL at 0,5, 1, 2 and 3 kHz;

c) average of HTL at 0,5, 1, 2 and 4 kHz;

d) average of HTL at 1, 2 and 3 kHz;

e) average of HTL at 1, 2, 3 and 4 kHz;

f) average of HTL at 2 and 4 kHz;

g) one-tenth of (2 × HTL at 0,5 kHz, 4 × HTL at 1 kHz, 3 × HTL at 2 kHz and 1 × HTL at 4 kHz);

h) HTL at 2 and 3 kHz;

i) average of HTL at 2, 3 and 4 kHz.

The equations may apply to individual ears, average of both ears or a weighted average of both ears.

Other procedures for determining the overall percentage of loss of hearing for compensation purposes require the hearing threshold level of both ears measured at 0,5, 1, 1,5, 2, 3 and 4 kHz. The percentage loss of hearing for each frequency may then be determined from tables with the hearing threshold level of the better and of the worse ear as variables. The overall percentage loss of hearing may be obtained by adding up the percentages contributed by each frequency.

6.3 Risk of hearing handicap

The risk of hearing handicap due to noise exposure and age, or due to noise exposure alone, are frequently used measures of the harmful effects of noise exposures on a population. A fence may be selected for the hearing threshold level above which a hearing handicap is deemed to exist. Then the fractile of the population which has an average hearing threshold level equal to or exceeding the level selected for the fence may be calculated. The risks of hearing handicap due to the combined effects of noise exposure and age and the risk of hearing handicap due to noise alone may then be derived according to their definitions.

NOTES

1 The choice of equation and the height of the fence, though determined primarily by medico-legal considerations, may be also influenced by economic and ethical considerations.

2 An example for the assessment of risk of hearing handicap due to occupational noise exposure is illustrated in annex D.

3 The risk of hearing handicap due to noise should not be regarded as a single number descriptor. It varies with choice of frequency combination, choice of fence and choice of HTLA. When quoting the risk of hearing handicap due to noise, the parameters mentioned should be quoted as well.

4 The risk of hearing handicap due to noise gives the fractile of a population whose HTLAN exceeds the fence. It does **not** indicate the severity of the hearing handicap as such.

5 In the fractile of a population affected by hearing handicap due to noise, the HTLAN is still a combination of components associated with both age and noise, of which the relative importance varies.

6 With some data bases for HTLA and certain choices of frequency combinations and fence, the risk of hearing handicap due to noise may **decrease** after a number of years of exposure. This is an inherent disadvantage of the concept "risk of hearing handicap". It should not be interpreted as if the harmful effects of noise cease to exist. The explanation is that people who have crossed the fence because of age-related threshold shifts are no longer eligible for a risk of hearing handicap due to noise. See also notes 4 and 5.

Annex A
(informative)

Calculation of data base A, hearing threshold level assocated with age (HTLA) for an otologically normal population ("highly screened")

A.1 Specification of data base A

The values for data base A are identical with the normal threshold of hearing by air conduction specified as a function of age and sex in ISO 7029. The equations applicable for the hearing threshold level H as a function of age Y (years) for the various ranges of the fractile Q having hearing threshold level exceeding the value H_Q are

For $0{,}05 \leqslant Q < 0{,}50$ $H_Q = H_{0,50} + kS_u$

For $Q = 0{,}50$ $H_{0,50} = a\,(Y-18)^2 + H_{0,50;\,18}$

For $0{,}50 < Q \leqslant 0{,}95$ $H_Q = H_{0,50} - kS_l$

$H_{0,50;\,18}$ is the median value of hearing threshold of otologically normal persons of the same sex aged 18 years, which for practical purposes is taken as zero as specified in ISO 389. Hence, for the purpose of this International Standard, H_Q has been termed the hearing threshold level associated with age.

The values for the coefficient a are presented in table A.1. The values for the multiplier k are the same as the ones given in 5.3.2.1 and in table 3. The parameters S_u and S_l are given by the equations

$$S_u = b_u + 0{,}445\,H_{0,50}$$

$$S_l = b_l + 0{,}356\,H_{0,50}$$

Values of b_u and b_l are listed in table A.2.

Table A.1 — Values of the coefficient a

Frequency Hz	Value of a	
	Males	Females
125	0,003 0	0,003 0
250	0,003 0	0,003 0
500	0,003 5	0,003 5
1 000	0,004 0	0,004 0
1 500	0,005 5	0,005 0
2 000	0,007 0	0,006 0
3 000	0,011 5	0,007 5
4 000	0,016 0	0,009 0
6 000	0,018 0	0,012 0
8 000	0,022 0	0,015 0

Table A.2 — Values of b_u and b_l used to determine respectively the upper and lower parts of the statistical distribution H_Q

Frequency Hz	Value of b_u		Value of b_l	
	Males	Females	Males	Females
125	7,23	6,67	5,78	5,34
250	6,67	6,12	5,34	4,89
500	6,12	6,12	4,89	4,89
1 000	6,12	6,12	4,89	4,89
1 500	6,67	6,67	5,34	5,34
2 000	7,23	6,67	5,78	5,34
3 000	7,78	7,23	6,23	5,78
4 000	8,34	7,78	6,67	6,23
6 000	9,45	8,90	7,56	7,12
8 000	10,56	10,56	8,45	8,45

A.2 Selected values from data base A

Selected values are given in table A.3.

Table A.3 — Selected values of hearing threshold level, in decibels, from data base A

Frequency Hz	Hearing threshold level, dB											
	Age, years											
	30			40			50			60		
	Fractiles											
	0,9	0,5	0,1	0,9	0,5	0,1	0,9	0,5	0,1	0,9	0,5	0,1
Males												
500	−6	1	9	−5	2	11	−4	4	14	−3	6	18
1 000	−6	1	9	−5	2	11	−4	4	14	−2	7	19
2 000	−7	1	11	−6	3	15	−4	7	21	−1	12	29
3 000	−7	2	13	−5	6	19	−2	12	29	3	20	42
4 000	−7	2	14	−4	8	23	0	16	37	7	28	55
6 000	−8	3	16	−5	9	26	0	18	41	8	32	62
Females												
500	−6	1	9	−5	2	11	−4	4	14	−3	6	18
1 000	−6	1	9	−5	2	11	−4	4	14	−2	7	19
2 000	−6	1	10	−5	3	13	−3	6	18	−1	11	25
3 000	−7	1	11	−5	4	15	−3	8	21	0	13	30
4 000	−7	1	12	−6	4	17	−3	9	25	1	16	35
6 000	−8	2	14	−6	6	21	−2	12	31	2	21	45

Annex B
(informative)

Example for data base B

This example for data base B comprises hearing threshold levels associated with age of a typical unscreened population (males and females) of an industrialized country (data are for the better ear).

NOTES

1 The data are adapted from the results of a particular survey (see annex F, [3] and [13]). Some subjects in the population tested have to be assumed to have had unreported occupational or other noise exposure. For another example for data base B, see [18].

2 The hearing threshold levels associated with age are in decibels with reference to audiometric zero as defined in ISO 389.

Table B.1 — Hearing threshold levels, in decibels, of an unscreened population

Frequency Hz	Hearing threshold level, dB											
	Age, years											
	30			40			50			60		
	Fractiles											
	0,9	0,5	0,1	0,9	0,5	0,1	0,9	0,5	0,1	0,9	0,5	0,1
Males												
500	−1	7	15	0	8	19	1	10	21	2	12	26
1 000	−5	0	10	−4	3	15	−3	5	16	−2	6	21
2 000	−4	2	13	−3	4	19	−2	8	28	0	10	43
3 000	−1	9	20	2	13	41	5	19	51	9	30	62
4 000	−1	10	38	4	17	50	8	26	54	12	36	68
6 000	8	18	32	11	24	62	17	31	62	22	46	80
Females												
500	−1	6	15	0	7	19	1	10	23	4	14	29
1 000	−6	1	9	−5	2	13	4	4	16	−2	7	21
2 000	−6	0	10	−4	2	13	−2	6	23	0	8	29
3 000	−4	4	13	−2	6	18	0	9	26	6	16	37
4 000	−5	4	16	−4	6	18	−1	9	26	4	17	43
6 000	3	12	25	5	15	31	8	20	45	15	29	57

Annex C
(informative)

Selected hearing threshold levels associated with age

This annex comprises average HTLA values for three values of Q averaged for the frequency combination 0,5, 1 and 2 kHz which, when used with the NIPTS values calculated in accordance with this International Standard, results in approximately the same hearing risk as predicted by the first edition of ISO 1999. [The fit is reasonable for exposures to A-weighted sound pressure levels of 95 dB, but the risk may deviate up to 10 percentage points for other levels, see table 25 in [13] (see annex F).]

Table C.1 — Average HTLA values, in decibels

	Age 28 years			Age 38 years			Age 48 years			Age 58 years		
Fractiles	0,90	0,50	0,10	0,90	0,50	0,10	0,90	0,50	0,10	0,90	0,50	0,10
HTLA	8	15	21	9	16	23,5	9	17,5	26	10	22	32

Annex D
(informative)

Example of assessment of risk of noise-induced hearing impairment

Calculate the risk of noise-induced hearing impairment for a male population, 50 years of age, which was exposed to an average daily noise exposure level, $L_{EX,8h}$ = 90 dB ($E_{A,8h}$ = $11{,}5 \times 10^3$ $Pa^2 \cdot s$) daily for 30 years (8 h/day, 5 days/week, 50 weeks/year).

For handicap assessment the frequency combination 1, 2 and 4 kHz is assumed. The age-related hearing threshold level H_Q for the non-noise-exposed population is calculated in accordance with data base A (see annex A) and averaged for the frequencies 1, 2 and 4 kHz.

$$H_{0,9;50} = [(-4) + (-4) + 0]/3 = -2{,}7 \text{ dB}$$

$$H_{0,5;50} = (4 + 7 + 16)/3 = 9{,}0 \text{ dB}$$

$$H_{0,1;50} = (14 + 21 + 37)/3 = 24{,}0 \text{ dB}$$

For the frequencies of 1 000 Hz and 2 000 Hz and the 0,9 and 0,5 fractiles of 4 000 Hz, the noise-induced permanent threshold shift in this case can be directly taken from table E.2 in annex E, since

$$N - \frac{HN}{120} \approx N$$

For the frequency of 4 000 Hz, the sum of $H + N$ for the fractile of 0,1 is greater than 40 dB. Therefore, the value of 19 dB from table E.2 in annex E is reduced as follows:

$$19 - \frac{37 \times 19}{120} = 13{,}1 \text{ dB}$$

The noise-induced permanent threshold shift values are therefore:

$$N_{0,9;30} = (0 + 3 + 10)/3 = 4{,}3 \text{ dB}$$

$$N_{0,5;30} = (0 + 5 + 14)/3 = 6{,}3 \text{ dB}$$

$$N_{0,1;30} = (0 + 9 + 13{,}1)/3 = 7{,}4 \text{ dB}$$

and consequently results in the distribution of the hearing threshold level associated with age and noise (HTLAN) for the noise-exposed population as follows:

$$H'_{0,9} = 1{,}6 \text{ dB}$$

$$H'_{0,5} = 15{,}3 \text{ dB}$$

$$H'_{0,1} = 31{,}4 \text{ dB}$$

The resulting relationship is plotted in figure D.1 on Gaussian coordinates with the various risks of handicap illustrated for an arbitrary "fence" of 27 dB. The dependence of the risk values on the magnitude of the fence can easily be studied with such an illustration.

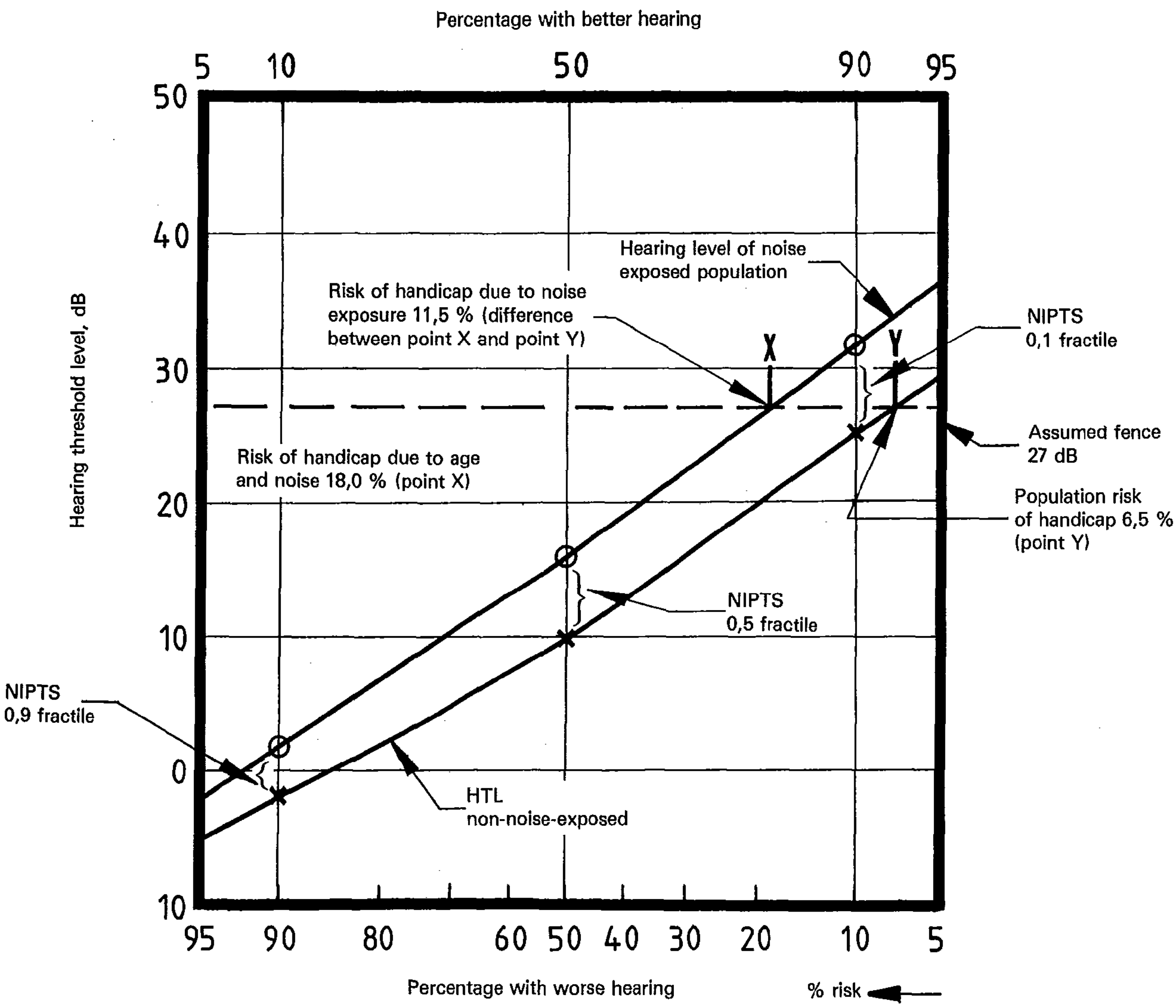

Figure D.1 — Example of hearing risk assessment: noise exposure level $L_{EX, 8h}$ = 90 dB for 30 years exposure with HTLA data from data base A

Annex E
(informative)

Tables with examples for NIPTS data

Tables with examples for NIPTS as a function of exposure time, in years, and noise exposure level, $L_{EX,\,8h}$ (85, 90, 95, 100 dB) and corresponding A-weighted sound exposures for six frequencies (0,5, 1, 2, 3, 4 and 6 kHz) and three fractiles (0,1, 0,5 and 0,9) calculated in accordance with 5.3 of this International Standard.

Table E.1 — $L_{EX,\,8h}$ = 85 dB ($E_{A,8h}$ = 3,64 × 10^3 $Pa^2 \cdot s$)

Frequency Hz	NIPTS, dB											
	Exposure time, years											
	10			20			30			40		
	Fractiles											
	0,9	0,5	0,1	0,9	0,5	0,1	0,9	0,5	0,1	0,9	0,5	0,1
500	0	0	0	0	0	0	0	0	0	0	0	0
1 000	0	0	0	0	0	0	0	0	0	0	0	0
2 000	0	1	1	1	1	2	1	1	2	1	2	2
3 000	2	3	5	3	4	6	3	4	7	3	5	7
4 000	3	5	7	4	6	8	5	6	9	5	7	9
6 000	1	3	4	2	3	5	2	3	6	2	4	6

Table E.2 — $L_{EX,\,8h}$ = 90 dB ($E_{A,8h}$ = 11,5 × 10^3 $Pa^2 \cdot s$)

Frequency Hz	NIPTS, dB											
	Exposure time, years											
	10			20			30			40		
	Fractiles											
	0,9	0,5	0,1	0,9	0,5	0,1	0,9	0,5	0,1	0,9	0,5	0,1
500	0	0	0	0	0	0	0	0	0	0	0	0
1 000	0	0	0	0	0	0	0	0	0	0	0	0
2 000	0	2	6	2	4	8	3	5	9	4	6	10
3 000	4	8	13	7	10	16	8	11	18	9	12	19
4 000	7	11	15	9	13	18	10	14	19	11	15	20
6 000	3	7	12	4	8	14	5	9	15	6	10	15

Table E.3 — $L_{EX,\,8h}$ = 95 dB ($E_{A,8h}$ = 36,4 × 10^3 $Pa^2 \cdot s$)

Frequency Hz	NIPTS, dB											
	Exposure time, years											
	10			20			30			40		
	Fractiles											
	0,9	0,5	0,1	0,9	0,5	0,1	0,9	0,5	0,1	0,9	0,5	0,1
500	0	0	1	0	0	1	0	1	1	0	1	1
1 000	1	2	4	2	3	5	2	3	5	2	3	6
2 000	0	5	13	5	9	17	7	12	20	9	14	22
3 000	8	16	25	13	19	31	16	22	34	18	23	37
4 000	13	20	27	16	23	32	18	25	34	19	26	36
6 000	5	14	23	8	16	26	10	18	28	12	19	29

Table E.4 — $L_{EX,\,8h}$ = 100 dB ($E_{A,8h}$ = 115 × 10^3 $Pa^2 \cdot s$)

Frequency Hz	NIPTS, dB											
	Exposure time, years											
	10			20			30			40		
	Fractiles											
	0,9	0,5	0,1	0,9	0,5	0,1	0,9	0,5	0,1	0,9	0,5	0,1
500	2	4	8	3	5	9	4	6	11	5	7	11
1 000	3	6	12	6	9	15	7	10	17	8	11	19
2 000	0	8	23	8	16	31	13	21	35	16	24	39
3 000	13	26	41	21	32	51	26	35	56	29	38	60
4 000	20	31	42	25	36	49	28	39	53	30	41	56
6 000	9	23	37	14	27	42	17	29	46	19	30	48

Annex F
(informative)

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