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Acoustics — Assessment of occupational noise exposure for hearing conservation purposes

Acoustique — Estimation de l'exposition au bruit durant le travail en vue de la protection de l'audition

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up 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.

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.

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Prior to 1972, the results of the work of the Technical Committees were published as ISO Recommendations; these documents are now in the process of being transformed into International Standards. As part of this process, Technical Committee ISO/TC 43 has reviewed ISO Recommendation R 1999 and found it technically suitable for transformation. International Standard ISO 1999 therefore replaces ISO Recommendation R 1999-1971 to which it is technically identical.

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ISO Recommendation R 1999 was approved by the Member Bodies of the following countries :

Austria	Germany	South Africa, Rep. of
Belgium	Greece	Sweden
Canada	Hungary	Switzerland
Czechoslovakia	Ireland	United Kingdom
Denmark	Netherlands	U.S.A.
Egypt, Arab Rep. of	New Zealand	U.S.S.R.
France	Norway	

The Member Body of the following country expressed disapproval of the Recommendation on technical grounds :

Japan

The Member Bodies of the following countries disapproved the transformation of ISO/R 1999 into an International Standard :

Germany
United Kingdom

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The human hearing mechanism can be impaired by noise exposure. The degree of impairment depends on the noise level and duration as well as on the sensitivity of the individual.

In many cases permanent impairment of hearing due to noise exposure develops over years resulting in a severe hearing loss greatly affecting the faculty of communication by speech.

This International Standard results from the need for methods by which the risk for noise-induced impairment of hearing can be estimated. The existence of such methods will make it easier for interested bodies to set up limits for tolerable noise exposure during work and for the institution of hearing conservation programmes.

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Emphasis is put on a simple but sufficiently reliable method for sound measurement, a method which can be used also by people without special acoustical knowledge.

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The complicated problems connected with the effect of recovery periods within the working day have been considered, but it was felt that further research and consideration were necessary before simple rules applicable to such effects could be established. Similar remarks also apply to some types of impulsive noise.

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Acoustics — Assessment of occupational noise exposure for hearing conservation purposes

0 INTRODUCTION

This International Standard gives a practical relation between noise exposure, expressed in terms of noise level and duration, and the percentage of people that may be expected to show hearing impairment solely as a result of occupational noise exposure.

Hearing impairment can be expressed, for many purposes, in terms of threshold shift at various frequencies. In most cases, however, the previous audiometric history is not available, so that prescriptions in terms of hearing level are necessary. Thus, for the retention of the faculty to understand conversational speech, a limit may be set to the permitted hearing level at frequencies of importance for the intelligibility of speech.

In this International Standard the recommendations and data are based primarily on the impairment criterion that hearing is considered impaired if the arithmetic average of the permanent threshold shifts for the three frequencies 500, 1 000 and 2 000 Hz is 25 dB or more.

It is appreciated that for some purposes it may be necessary to widen the frequency range over which the hearing levels are averaged and to vary the criterion for the hearing level.

The manner in which noise exposure is related to hearing impairment, for the purpose of this International Standard, is through the concept of "risk", defined below, this being an expression of the probability that exposed persons will acquire a specified degree of hearing impairment.

The levels and durations of the noises concerned are measured and an additive index is assigned to each. The sum of these indices is converted to a continuous noise level considered to be equally hazardous to hearing. A table is given to show the percentage of workers for which impairment of hearing according to the above impairment criterion will occur solely as a result of exposure to this noise during normal working time in periods of up to 45 years, the effects of age also being taken into account. Therefore, this International Standard provides a basis for the fixing of tolerable limits for noise exposure under working conditions by appropriate bodies.

It should be emphasized that if noise control methods are necessary in order to keep the exposure below fixed limits, more complicated measurements than those described in the main body of this International Standard may be necessary. An example of this is given in annex A.

1 SCOPE AND FIELD OF APPLICATION

This International Standard gives a practical relation between occupational noise exposure, expressed in terms of A-weighted sound level in dB (commonly called dB (A)) and duration within a normal working week (assumed to be 40 h), and the percentage of the workers that may be expected to exhibit an increased threshold of hearing amounting to 25 dB or more averaged over the three frequencies 500, 1 000 and 2 000 Hz solely as a result of the noise exposure.

It is not applicable to impulsive noises consisting of noise of a duration less than 1 s or single high-level transients of a very short duration, for example from gunfire.

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2 REFERENCES

ISO 389, *Standard reference zero for the calibration of pure-tone audiometers.*

ISO 1999:1975
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IEC Publication 123, *Recommendations for sound level meters.*

IEC Publication 179, *Precision sound level meters.*

IEC Publication 225, *Octave, half-octave and third-octave band filters intended for the analysis of sound and vibrations.*

3 DEFINITIONS

For the purposes of this International Standard the following definitions apply :

3.1 partial noise exposure index : An index determined by a sound level and its duration within a working week (40 h).

3.2 composite noise exposure index : The sum of partial noise exposure indices for all relevant sound levels over a working week (40 h).

3.3 equivalent continuous sound level : That sound level in dB (A) which, if present for 40 h in 1 week, produces the same composite noise exposure index as the various measured sound levels over 1 week.

3.4 impairment of hearing for conversational speech : The hearing of a subject is considered to be impaired if the arithmetic average of the permanent threshold hearing

levels of the subject for 500, 1 000 and 2 000 Hz is shifted by 25 dB or more compared with the corresponding average given in ISO 389.

3.5 risk : The difference between the percentage of people with impaired hearing in a noise-exposed group and the percentage of people with impaired hearing in a non-noise-exposed (but otherwise equivalent) group.

3.6 risk of hearing impairment for conversational speech : The particular value of risk when the impairment of hearing in question is as described in 3.4.

4 NOISE MEASUREMENTS

The sound level at the approximate position occupied by the listener's ear (but preferably with the listener absent) should be determined over an appropriate time and expressed in dB (A).

If the sound level averaged over a short time (i.e. several seconds or minutes) is almost unchanged within a week or varies in a regular manner among a few clearly distinguishable levels, the measurements may be made with a sound level meter with A-weighting set at "slow" response. The meter should be in accordance with IEC Publication 123 or IEC Publication 179.

In other cases a statistical analysis of the noise level over a typical period should be made with automatic recording equipment having a performance which equates with the sound level meter used under similar conditions.

In either of these cases, the occurring noise levels should be grouped in classes with a width of 5 dB each. The level and total duration within a week should be recorded for each class.

Noises for which the sound level is less than 80 dB (A) may be disregarded, if there are no corrections to be added in accordance with clause 6 of this International Standard. If corrections are necessary, this rule applies to the corrected value.

5 CALCULATION OF EQUIVALENT CONTINUOUS SOUND LEVEL FOR NON-IMPULSIVE SOUND THAT IS INTERMITTENT OR FLUCTUATING

The procedure for the calculation of equivalent continuous sound level consists of the three following steps :

Step 1

The total duration during 1 week of each sound level is entered at the first column of table 1 and the partial noise exposure index read at the intersection with the appropriate sound level.

If the total weekly duration is less than 10 min, the minimum value of 10 min should be used.

Step 2

The arithmetical sum of the partial noise exposure indices so obtained is the composite noise exposure index.

Step 3

Enter this value of composite noise exposure index in table 2 and read off the equivalent continuous sound level.

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6 CALCULATION OF EQUIVALENT CONTINUOUS SOUND LEVEL OF QUASI-STABLE IMPULSIVE NOISE

The method specified in this International Standard is not applicable to impulsive noises consisting of single bursts of noise of a duration less than 1 s or single high-level transients of a very short duration, for example from gunfire.

However, for impulsive noise consisting of series of noise bursts of approximately equal amplitudes (for example noise from rapidly repeated hammering or riveting) an approximation to the partial noise exposure index may be based on a value 10 dB (A) higher than the measured sound level.

A more precise definition of the cases where a correction should be applied is desirable, but this problem can only be solved when the results of further research become available.

TABLE 1 – **Partial noise exposure indices for sound levels 80 to 120 dB (A) and duration 10 min to 40 h per week**

Duration per week		Partial noise exposure indices								
		Sound level in dB (A) (Class midpoint)								
h	min	80	85	90	95	100	105	110	115	120
	10					5	15	40	130	415
	12					5	15	50	160	500
	14					5	20	60	185	585
	16					5	20	65	210	665
	18					10	25	75	235	750
	20					10	25	85	265	835
	25				5	10	35	105	330	1 040
	30				5	15	40	125	395	1 250
	40				5	15	55	165	525	1 670
	50				5	20	70	210	660	2 080
	60			5	10	25	80	250	790	2 500
	70			5	10	30	90	290	920	2 920
	80			5	10	35	105	330	1 050	3 330
	90			5	10	40	120	375	1 190	3 750
	100			5	15	40	130	415	1 320	4 170
2				5	15	50	160	500	1 580	5 000
2,5				5	20	65	200	625	1 980	6 250
3				10	25	75	235	750	2 370	7 500
3,5			5	10	30	90	275	875	2 770	8 750
4			5	10	30	100	315	1 000	3 160	10 000
5			5	15	40	125	395	1 250	3 950	12 500
6			5	15	45	150	475	1 500	4 740	15 000
7			5	20	55	175	555	1 750	5 530	17 500
8			5	20	65	200	630	2 000	6 320	20 000
9			5	25	70	225	710	2 250	7 110	22 500
10		5	10	25	80	250	790	2 500	7 910	25 000
12		5	10	30	95	300	950	3 000	9 490	30 000
14		5	10	35	110	350	1 110	3 500	11 100	
16		5	15	40	125	400	1 260	4 000	12 600	
18		5	15	45	140	450	1 420	4 500	14 200	
20		5	15	50	160	500	1 580	5 000	15 800	
25		5	20	65	200	625	1 980	6 250	19 800	
30		10	25	75	235	750	2 370	7 500	23 700	
35		10	30	90	275	875	2 770	8 750	27 700	
40		10	30	100	315	1 000	3 160	10 000	31 600	

The values are calculated from the formula :

$$E_i = \frac{\Delta t_i}{40} 10^{0,1\,(L_i - 70)}$$

where

E_i is the partial noise exposure index;

L_i is the sound level A in dB corresponding to the midpoint of the class i;

Δt_i is the total duration in hours per week of sound levels within the class i.

TABLE 2 – **Relation between composite noise exposure index and equivalent continuous sound level**

Composite noise exposure index	Equivalent continuous sound level, dB (A)
10	80
15	82
20	83
25	84
30	85
40	86
50	87
60	88
80	89
100	90
125	91
160	92
200	93
250	94
315	95
400	96
500	97
630	98
800	99
1 000	100
1 250	101
1 600	102
2 000	103
2 500	104
3 150	105
4 000	106
5 000	107
6 300	108
8 000	109
10 000	110
12 500	111
16 000	112
20 000	113
25 000	114
31 500	115

The values are calculated from the formula :

$$L_{eq} = 70 + 10 \log_{10} \Sigma E_i$$

where

L_{eq} is the equivalent continuous sound level in dB (A);

E_i is the partial noise exposure index (from table 1).

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7 ESTIMATION OF RISK INVOLVED

Annex B gives, in the upper row *a*) of each entry, the risk of hearing impairment for conversational speech (as defined in 3.6) as a function of equivalent sound level and years of exposure during working hours, on the assumption of a 40 h week and 50 weeks per year. In the lower row *b*) of each entry, it also gives the total percentage of people with impaired hearing in a noise-exposed group. For information, the case of $L_{eq} \leqslant 80$ dB (A) is included, the lower row *b*) being the percentage of persons with impaired hearing in a non-noise-exposed group; this value is equal to the difference between corresponding table entries *b*) and *a*) for any noise-exposed group. The percentages are rounded off to the nearest integer.

NOTES

1 Limits for tolerable noise exposure during work may be set by competent authorities who generally demand the institution of hearing conservation programmes if the limits are exceeded. In many cases, 85 to 90 dB (A) equivalent continuous sound level has been chosen.

2 Corresponding tables of risk may be constructed by the competent authorities for risks other than that defined in 3.6, as data become available.

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ANNEX A

CALCULATION OF THE EQUIVALENT CONTINUOUS SOUND LEVEL RESULTING FROM NOISE ABATEMENT MEASURES

The procedures described in the main body of this International Standard may not be adequate when the reduction of the noise exposure resulting from noise abatement measures is to be estimated.

For this purpose 1/1 octave or 1/3 octave analysis of the noise is generally necessary.

As an example, the procedure for estimating the equivalent continuous sound level for a subject wearing ear protectors is indicated below.

Step 1

Make a measurement of the noise according to clause 4 of this International Standard, but with octave band filters according to IEC Publication 225 inserted in the measuring chain in place of the A-weighting network.

Step 2

Compute the equivalent continuous sound level for each octave band, according to clause 5. (In cases where the sound spectrum does not change materially during the working time, this step can be omitted.)

Step 3

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Apply A-weighting corrections to the octave band levels so obtained as follows :

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Octave centre frequency, Hz	63	125	250	500	1 000	2 000	4 000	8 000
Corrections, dB	− 26	− 16	− 9	− 3	0	+ 1	+ 1	− 1

Step 4

Subtract from these corrected octave band levels the attenuation values of the ear protector in question in the respective octave bands. Term the resulting levels L_{63} to $L_{8\,000}$.

Step 5

Calculate the equivalent continuous sound level L_{eq} from the formula :

$$L_{eq} = 10 \log_{10} \left(\text{antilog}_{10} \frac{L_{63}}{10} + \text{antilog}_{10} \frac{L_{125}}{10} + \ldots + \text{antilog}_{10} \frac{L_{8\,000}}{10} \right)$$

From this value the risk when wearing personal ear protectors of the type assumed can be determined.