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Acoustics — Hearing protectors —

Part 2:
Estimation of effective A-weighted sound pressure levels when hearing protectors are worn

Acoustique — Protecteurs individuels contre le bruit —

Partie 2: Estimation des niveaux de pression acoustique pondérés A en cas d'utilisation de protecteurs individuels contre le bruit

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Foreword

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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 (see www. iso. org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www. iso.org/patents).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www. iso. org/iso/foreword. html.

This document was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise.*

This second edition cancels and replaces the first edition (ISO 4869-2:1994) which has been technically revised. It also incorporates the corrected version ISO 4869-2:1994/Cor.1:2006.

The main technical changes are:

In the prior edition of the standard the *H*, *M*, *L*, and *SNR* values were computed from the group average data by frequency. In this edition, the values are computed subject by subject and then combined to provide both a mean value and a standard deviation value so that population distribution can be estimated. The sound attenuation values for the frequency 63 Hz have been excluded from the *H*, *M*, *L* and *SNR* calculation methods since this test frequency is optional in ISO 4869-1. Prior to rounding to the nearest integer, values derived using this edition deviate from those derived using the previous edition by less than 1 dB.

A list of all parts in the ISO 4869 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document estimates an “effective” level, i.e. the A-weighted sound pressure level at the head centre with the listener absent, minus the attenuation of the hearing protection devices. Effective values are estimated since those are required to assess noise hazard with respect to permissible noise exposure limits. An effective level differs from that in the ear canal since it has been converted to a sound-field value via the transfer function of the open ear. Effective levels are typically 5 dB to 10 dB less than ear canal levels depending on the spectrum of the incident noise.

Ideally, the A-weighted sound pressure level effective when a hearing protector is worn should be estimated on the basis of both the octave-band sound attenuation data of the hearing protector (measured in accordance with ISO 4869-1) and the octave-band sound pressure levels of the noise. It is recognized, however, that in many situations information on the octave-band sound pressure levels of the noise might not be available. Therefore, for many practical purposes, there is a need for simpler methods to determine the effective A-weighted sound pressure levels which are only based on the A- and C-weighted sound pressure levels of the noise. This document addresses both of these situations by specifying an octave-band calculation method as well as two alternative simplified procedures, the *HML* method and the *SNR* method.

The octave-band method is a calculation method involving the workplace octave-band sound pressure levels and the octave-band sound attenuation data for the hearing protector that is being assessed. Although it can be thought of as an "exact" reference method, it has its own inherent inaccuracies, since it is based upon mean sound attenuation values and standard deviations for a group of test subjects, and not the specific sound attenuation values for the individual person in question.

The *HML* method specifies three attenuation values, *H*, *M* and *L*, determined from the octave-band sound attenuation data of a hearing protector. These values, when combined with the C- and A-weighted sound pressure levels of the noise, are used to calculate the effective A-weighted sound pressure level when the hearing protector is worn.

The *SNR* method specifies a single attenuation value, the single number rating, determined from the octave-band sound attenuation data of a hearing protector. This value is subtracted from the C-weighted sound pressure level of the noise to calculate the effective A-weighted sound pressure level when the hearing protector is worn.

Due to the large spread of the sound attenuation provided by hearing protectors when worn by individual persons, all three methods are nearly equivalent in their accuracy in the majority of noise situations. Even the simplest method, the *SNR* method, will provide a reasonably accurate estimate of the effective A-weighted sound pressure level to aid in the selection and specification of hearing protectors. In special situations, for example especially high- or low-frequency noises, it is necessary to use either the *HML* or the octave-band method.

Depending on the choice of a certain parameter in the calculation process, various protection performances can be obtained. It should be noted that the protection performance values for all three methods are only valid when:

— the hearing protectors are worn correctly and in the same manner as they were worn by subjects when carrying out the ISO 4869-1 test;

— the hearing protectors are properly maintained;

— the anatomical characteristics of the subjects involved in the ISO 4869-1 test are a reasonable match for the population of actual wearers.

Thus, the principal source of potential inaccuracy in use of the three methods described in this document is the basic ISO 4869-1 input data. If the input data do not accurately describe the degree of protection achieved by the target population, then no calculation method will provide sufficient accuracy.

The uncertainty of the attenuation values and ratings is described in Annex E.

NOTE Differences of 3 dB or less in the determination of the effective sound pressure level for comparable hearing protectors are generally insignificant.

Acoustics — Hearing protectors —

Part 2:
Estimation of effective A-weighted sound pressure levels when hearing protectors are worn

1 Scope

This document specifies three methods (the octave-band, *HML* and *SNR* methods) of estimating the A-weighted sound pressure levels effective when hearing protectors are worn. The methods are applicable to either the sound pressure level or the equivalent continuous sound pressure level of the noise. Although primarily intended for steady noise exposures, the methods are also applicable to noises containing impulsive components. It is possible that these methods could not be suitable for use with peak sound pressure level measurements.

The octave-band, *H*, *M*, *L* or *SNR* values are suitable for establishing sound attenuation criteria for selecting or comparing hearing protectors, and/or setting minimum acceptable sound attenuation requirements.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4869-1, *Acoustics — Hearing protectors — Part 1: Subjective method for the measurement of sound attenuation*

ISO 9612:2009, *Acoustics — Determination of occupational noise exposure — Engineering method*

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4869-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
protection performance
x
percentage of individuals for which the achieved protection is equal to or greater than the designated value, where the percentage is indicated by adding a subscript to the symbols representing the different methods, e.g. APV_{fx}, H_x, M_x, L_x, SNR_x

Note 1 to entry: The value of protection performance is often chosen to be 84 % [corresponding to the constant $\alpha = 1$ (see Clause 5)].

3.2
effective A-weighted sound pressure level
$L'_{p,Ax}$
A-weighted sound pressure level effective when a given hearing protector is worn for a specified protection performance, x, and a specific noise situation

Note 1 to entry: It is calculated in accordance with any of the three methods specified in ISO 4869-2.

3.3
predicted noise level reduction
PNR_x
difference between the A-weighted sound pressure level of the noise, $L_{p,A}$, and the effective A-weighted sound pressure level, $L'_{p,Ax}$ when a given hearing protector is worn for a specified protection performance, x, and a specific noise situation

3.4
assumed protection value
APV_{fx}
value representing the attenuation in that octave band for a particular octave band, f, a specified protection performance, x, and a given hearing protector

3.5
high-frequency attenuation value
H_x
value representing the predicted noise level reduction, PNR_x, for noises with $(L_{p,C} - L_{p,A}) = -2$ dB for a specified protection performance, x, and a given hearing protector

3.6
medium-frequency attenuation value
M_x
value representing the predicted noise level reduction, PNR_x, for noises with $(L_{p,C} - L_{p,A}) = +2$ dB for a specified protection performance, x, and a given hearing protector

3.7
low-frequency attenuation value
L_x
value representing the predicted noise level reduction, PNR_x, for noises with $(L_{p,C} - L_{p,A}) = +10$ dB for a specified protection performance, x, and a given hearing protector

3.8
single number rating
SNR_x
value that is subtracted from the measured C-weighted sound pressure level, $L_{p,C}$, in order to estimate the effective A-weighted sound pressure level, $L'_{p,Ax}$ for a specified protection performance, x, and a given hearing protector

4 Measurement of sound attenuation of hearing protectors

The one-third-octave-band attenuation values of the hearing protector to be used in the calculation methods specified in this part of ISO 4869 shall be measured in accordance with ISO 4869-1.

5 Calculation of the assumed protection value, APV_{fx}, of a hearing protector for a selected protection performance

The calculation begins with the selection of the desired protection performance, x, and the associated constant α (see Table 1). When $\alpha = 1$ and $x = 84$ %, the subscripts to the attenuation values may be omitted.

The assumed protection value, APV_{fx}, of the hearing protector is calculated for each octave band using the following formula:

$$APV_{fx} = m_f - \alpha\, s_f \qquad (1)$$

where

subscript f represents the centre frequency of the octave band;

subscript x represents the selected protection performance;

m_f is the mean sound attenuation determined in accordance with ISO 4869-1;

s_f is the standard deviation determined in accordance with ISO 4869-1;

α is the inverse of the standard normal cumulative distribution for a specific protection performance, having the values given in Table 1.

Table 1 — Values of α for various protection performances x

Protection performance x %	Value of α
50	0,00
75	0,67
80	0,84
84	1,00
90	1,28
95	1,64
98	2,00

An example of the calculation of the assumed protection values, APV_{fx}, is given in Annex A.

6 Octave-band method

This method requires octave-band sound pressure levels of the noise and assumed protection values, APV_{fx}. Since the method is noise specific, the calculation shall be made for each noise situation.

The A-weighted sound pressure level effective when the hearing protector is worn, $L'_{p,\mathrm{A}x}$, is calculated using the following formula:

$$L'_{p,\mathrm{A}x} = 10\,\lg \sum_{k=1}^{8} 10^{0,1\left(L_{p,f(k)} + \mathrm{A}_{f(k)} - APV_{f(k)x}\right)}\,\mathrm{dB} \qquad (2)$$

where

subscripts $f(k)$ represent the octave-band mid-frequency; $f(1)$ = 63 Hz; $f(2)$ = 125 Hz; $f(3)$ = 250 Hz; ...; $f(8)$ = 8 000 Hz;

$L_{p,f(k)}$ is the sound pressure level of the noise in the octave band;

$\mathrm{A}_{f(k)}$ is the frequency weighting A in accordance with IEC 61672-1 at the octave-band mid-frequencies (see Table B.1).

If 63 Hz octave-band data for either the noise or the hearing protector are not available, then the summation in Formula (2) begins at 125 Hz. For the subsequent *HML* and *SNR* methods the computations always begin at 125 Hz regardless of the availability of the data at 63 Hz. The resulting $L'_{p,Ax}$ value shall be rounded to the nearest integer.

An example of the estimation of the effective A-weighted sound pressure level when a given hearing protector is worn in a specific noise situation is given in Annex B.

7 *HML* method

7.1 General

This method requires C- and A-weighted sound pressure levels of the noise and *H*, *M* and *L* values.

7.2 Calculation of *H*, *M* and *L* values

Calculation of the H_x, M_x and L_x values in dB is based on eight reference noise spectra with different ($L_{p,C}$ − $L_{p,A}$) values (see Table 2) and the individual sound attenuation values, $\alpha_{jf(k)}$, of the hearing protector. The values are independent of the actual noise situation to which they are applied, and are calculated using the following formulae, where H_m, M_m, and L_m, refer to the mean values of the indices, and H_s, M_s, and L_s refer to the standard deviations of those indices:

$$H_x = H_m - \alpha H_s \tag{3}$$

$$M_x = M_m - \alpha M_s \tag{4}$$

$$L_x = L_m - \alpha L_s \tag{5}$$

where

subscript *x*	represents the selected protection performance;
α	is a constant specified in Table 1.

$$H_m = \frac{1}{N}\sum_{j=1}^{N} H_j \tag{6}$$

$$M_m = \frac{1}{N}\sum_{j=1}^{N} M_j \tag{7}$$

$$L_m = \frac{1}{N}\sum_{j=1}^{N} L_j \tag{8}$$

$$H_s = \sqrt{\frac{1}{N-1}\sum_{j=1}^{N}(H_j - H_m)^2} \tag{9}$$

$$M_s = \sqrt{\frac{1}{N-1}\sum_{j=1}^{N}(M_j - M_m)^2} \tag{10}$$

$$L_s = \sqrt{\frac{1}{N-1}\sum_{j=1}^{N}(L_j - L_m)^2} \tag{11}$$

$$H_j = 0{,}25\sum_{i=1}^{4} PNR_{ji} - 0{,}48\sum_{i=1}^{4} d_i\, PNR_{ji} \tag{12}$$

$$M_j = 0{,}25\sum_{i=5}^{8} PNR_{ji} - 0{,}16\sum_{i=5}^{8} d_i\, PNR_{ji} \tag{13}$$

$$L_j = 0{,}25\sum_{i=5}^{8} PNR_{ji} + 0{,}23\sum_{i=5}^{8} d_i\, PNR_{ji} \tag{14}$$

$$PNR_{ji} = 100\,\text{dB} - 10\lg\sum_{k=2}^{8} 10^{0{,}1\left(L_{p,Af(k)i} - a_{jf(k)}\right)}\text{dB} \tag{15}$$

where

N	is the number of subjects;
$a_{jf(k)}$	is the sound attenuation value in dB for subject j and frequency $f(k)$ determined in accordance with ISO 4869-1;
subscript j	represents the number of the test subject;
subscript i	represents the number of the reference noise spectrum;
$L_{p,\text{A}f(k)i}$ and d_i	values are given in Table 2.

NOTE In Formula (15), the value of 100 dB represents the total A-weighted sound pressure level of each of the noises in Table 2 specified for the octave bands from 125 Hz to 8 000 Hz.

The resulting H_x, M_x and L_x values shall be rounded to the nearest integer.

An example of the calculation of the H, M and L values is given in Annex C.

Table 2 — A-weighted octave-band sound pressure levels, $L_{p,\text{A}f(k)i}$, of eight reference noises, i, normalized to an A-weighted sound pressure level of 100 dB, $(L_{p,\text{C}} - L_{p,\text{A}})$ values and constants d_i

i	A-weighted octave-band sound pressure levels, $L_{p,\text{A}f(k)i}$, dB Octave-band centre frequency, f, Hz k							$(L_{p,\text{C}} - L_{p,\text{A}})$ dB	d_i
	125 $k = 2$	250 ...	500 ...	1 000 ...	2 000 ...	4 000 ...	8 000 $k = 8$		
1	62,6	70,8	81,0	90,4	96,2	94,7	92,3	−1,2	−1,20
2	68,9	78,3	84,3	92,8	96,3	94,0	90,0	−0,5	−0,49
3	71,1	80,8	88,0	95,0	94,4	94,1	89,0	0,1	0,14
4	77,2	84,5	89,8	95,5	94,3	92,5	88,8	1,6	1,56
5	77,4	86,5	92,5	96,4	93,0	90,4	83,7	2,3	−2,98
6	82,0	89,3	93,3	95,6	93,0	90,1	83,0	4,3	−1,01
7	84,2	90,1	93,6	96,2	91,3	87,9	81,9	6,1	0,85
8	88,0	93,4	93,8	94,2	91,4	87,9	79,9	8,4	3,14

NOTE 1 d_i is an empirically derived number[1][2].

NOTE 2 The value of 100 dB for the total A-weighted sound pressure level, $L_{p,\text{A}}$, is arbitrary and was chosen for computational simplicity.

7.3 Application of *HML* method for estimation of the effective A-weighted sound pressure level

The effective A-weighted sound pressure level, $L'_{p,\mathrm{A}x}$, is calculated in two steps as follows.

a) The predicted noise level reduction, PNR_x, is calculated from the H_x, M_x and L_x values and the C- and A-weighted sound pressure levels of the noise. The calculations are as follows.

For noises with $(L_{p,\mathrm{C}} - L_{p,\mathrm{A}}) \leq 2$ dB

$$PNR_x = M_x - \frac{H_x - M_x}{4}(L_{p,\mathrm{C}} - L_{p,\mathrm{A}} - 2\,\mathrm{dB}) \tag{16}$$

For noises with $(L_{p,\mathrm{C}} - L_{p,\mathrm{A}}) > 2$ dB

$$PNR_x = M_x - \frac{M_x - L_x}{8}(L_{p,\mathrm{C}} - L_{p,\mathrm{A}} - 2\,\mathrm{dB}) \tag{17}$$

b) $L'_{p,\mathrm{A}x}$ is calculated from the following formula:

$$L'_{p,\mathrm{A}x} = L_{p,\mathrm{A}} - PNR_x \tag{18}$$

The difference $(L_{p,\mathrm{C}} - L_{p,\mathrm{A}})$ can be estimated from sound pressure level measurements, long-term measurements of equivalent sound pressure levels, or may be provided in tabulated form for typical noise situations.

Instead of the C-weighted sound pressure level, the unweighted sound pressure level may be used. For very low frequency noises, this procedure will result in higher values of $L'_{p,\mathrm{A}x}$.

The resulting $L'_{p,\mathrm{A}x}$ value shall be rounded to the nearest integer.

An example of the estimation of the effective A-weighted sound pressure level when a given hearing protector is worn in a specific noise situation is given in Annex C.

8 *SNR* method

8.1 General

This method requires the C-weighted sound pressure level of the noise and the *SNR* value.

8.2 Calculation of *SNR* values

Calculation of SNR_x values, in dB, is based on a pink noise spectrum (see Table 3) and individual sound attenuation values, $a_{jf(k)}$, of the hearing protector.

SNR_x is independent of the actual noise spectrum to which it is applied and is calculated using the following formula, where SNR_m refers to the mean values of the *SNR* and SNR_s refers to the standard deviation of the *SNR*:

$$SNR_x = SNR_m - \alpha\, SNR_s \tag{19}$$

where

subscript x	represents the selected protection performance;
α	is a constant specified in Table 1.

$$SNR_m = \frac{1}{N}\sum_{j=1}^{N} SNR_j \qquad (20)$$

$$SNR_s = \sqrt{\frac{1}{N-1}\sum_{j=1}^{N}(\mathrm{SNR}_j - \mathrm{SNR}_m)^2} \qquad (21)$$

$$SNR_j = 100\,\mathrm{dB} - 10\,\lg \sum_{k=2}^{8} 10^{0,1(L_{p,\mathrm{A}f(k)} - a_{jf(k)})} \qquad (22)$$

where

N	is the number of subjects;
$a_{jf(k)}$	is the sound attenuation value in dB for subject j and frequency $f(k)$ determined in accordance with ISO 4869-1;
subscript j	represents the number of the test subject.

Values for $L_{p,\mathrm{A}f(k)}$ are given in Table 3.

NOTE In Formula (22) the value of 100 dB represents the total C-weighted sound pressure level of the reference pink noise in Table 3.

The resulting SNR_x value shall be rounded to the nearest integer.

An example of the calculation of SNR is given in Annex D.

8.3 Application of *SNR* method for estimation of the effective A-weighted sound pressure level

$L'_{p,\mathrm{A}x}$ is calculated from SNR_x and the C-weighted sound pressure level of the noise using the following formula:

$$L'_{p,\mathrm{A}x} = L_{p,\mathrm{C}} - SNR_x \qquad (23)$$

When only the total A-weighted sound pressure level of a given noise is available, SNR may still be used if the difference ($L_{p,\mathrm{C}} - L_{p,\mathrm{A}}$) is known. The difference ($L_{p,\mathrm{C}} - L_{p,\mathrm{A}}$) can be estimated from sound pressure level measurements, long-term measurements of equivalent sound pressure levels, or can be provided in tabulated form for typical noise situations. $L'_{p,\mathrm{A}x}$ is then given by:

$$L'_{p,\mathrm{A}x} = L_{p,\mathrm{A}} + (L_{p,\mathrm{C}} - L_{p,\mathrm{A}}) - SNR_x \qquad (24)$$

Instead of the C-weighted sound pressure level, the unweighted sound pressure level may be used. For very low frequency noises, this procedure will result in higher values of $L'_{p,\mathrm{A}x}$.

The resulting $L'_{p,\mathrm{A}x}$ value shall be rounded to the nearest integer.

An example of the estimation of the effective A-weighted sound pressure level when a given hearing protector is worn in a specific noise situation is given in Annex D.

Table 3 — A-weighted octave-band sound pressure levels, $L_{p,\mathrm{A}f(k)}$, of a pink noise which has a C-weighted sound pressure level of 100 dB

Octave-band centre frequency, *f* Hz	125	250	500	1 000	2 000	4 000	8 000
$L_{p,\mathrm{A}f(k)}$ dB	75,9	83,4	88,8	92,0	93,2	93,0	90,9
NOTE The values in this table are derived from a pink noise with an overall C-weighted sound pressure level of 100 dB. The magnitude of the level was chosen for computational simplicity and does not affect the resulting *SNR*. Frequency weighting C is defined in IEC 61672-1.							

Annex A
(informative)

Example of the calculation of the assumed protection values, APV_{fx}

In this example, the APV_{f84} values for a hearing protector are calculated; i.e. a protection performance of 84 % is selected, with a corresponding constant α = 1,00 (see Table 1). These APV_{f84} values are then used in the calculations for all illustrative examples.

Table A.1 — Calculation of APV_{f84}

Values in decibels

Subject, j	Sound attenuation Octave-band centre frequency, f Hz							
	63	125	250	500	1 000	2 000	4 000	8 000
1	4	8	13	18	20	30	35	30
2	6	12	16	21	29	35	47	35
3	10	16	17	23	25	32	48	37
4	3	7	12	18	20	25	33	30
5	8	10	16	16	25	27	43	32
6	4	7	10	15	19	32	35	31
7	5	5	9	16	20	25	30	28
8	15	15	21	26	25	38	46	38
9	5	6	10	13	19	22	29	28
10	9	9	10	19	20	27	37	31
11	9	16	18	24	25	35	44	39
12	5	6	11	12	17	20	28	28
13	7	10	17	22	25	35	41	44
14	6	8	16	18	19	19	30	33
15	10	12	17	25	28	33	45	40
16	12	13	17	27	29	38	49	41
m_f	7,4	10,0	14,4	19,6	22,8	29,6	38,8	34,1
s_f	3,3	3,6	3,6	4,6	4,0	6,2	7,4	5,2
$\alpha\, s_f$ (α = 1,00)	3,3	3,6	3,6	4,6	4,0	6,2	7,4	5,2
$APV_{f84} = m_f - \alpha\, s_f$	4,1	6,4	10,8	15,0	18,8	23,4	31,4	28,9

The calculation example shown here is provided via an Excel-sheet at standards.iso.org/iso/4869/-2/ed-2/en as well, by which the user may carry out own calculations.

Annex B
(informative)

Example of the calculation of $L'_{p,\mathrm{A}x}$ according to the octave-band method

In this example for a noise with $L_{p,\mathrm{A}}$ = 104 dB and a protection performance of 84 %, the APV_{f84} values are taken from Table A.1.

Table B.1 — Calculation of $L'_{p,\mathrm{A}84}$ using the octave-band method

Values in decibels

	Octave-band centre frequency, f Hz							
	63	125	250	500	1 000	2 000	4 000	8 000
Measured octave-band sound pressure level of the noise, $L_{p,f(k)}$	75,0	84,0	86,0	88,0	97,0	99,0	97,0	96,0
Frequency weighting A (according to IEC 61672-1)	−26,2	−16,1	−8,6	−3,2	0	+1,2	+1,0	−1,1
A-weighed octave-band sound pressure level of the noise, $L_{p,f(k)} + \mathrm{A}_{f(k)}$	48,8	67,9	77,4	84,8	97,0	100,2	98,0	94,9
$APV_{f(k)84}$ from Table A.1	4,1	6,4	10,8	15,0	18,8	23,4	31,4	28,9
$L_{p,f(k)} + \mathrm{A}_{f(k)} - APV_{f(k)84}$	44,7	61,5	66,6	69,8	78,2	76,8	66,6	66,0

$L'_{p,\mathrm{A}84}$ is calculated by substituting the values from the last row of Table B.1 into Formula (2):

$$L'_{p,\mathrm{A}84} = 10\lg(10^{0,1\times 44,7} + \ldots + 10^{0,1\times 66,0})\ \mathrm{dB} = 81,4\ \mathrm{dB}$$

After rounding, $L'_{p,\mathrm{A}84}$ = 81 dB.

It can then be stated that the effective A-weighted sound pressure level will be less than or equal to 81 dB in 84 % of the individuals when the hearing protector is properly worn by various people in this noise environment.

NOTE The difference between $L_{p,\mathrm{A}}$ and $L'_{p,\mathrm{A}84}$ is the predicted noise level reduction, PNR_{84}, which in this example is equal to 23 dB.

The calculation example shown here is provided via an Excel-sheet at standards.iso.org/iso/4869/-2/ed-2/en as well, by which the user may carry out own calculations.

Annex C
(informative)

Example of the calculation and use of *H*, *M* and *L* values

C.1 Calculation of *H*, *M* and *L* values for a particular hearing protector

The calculation is performed using the a_{jf} values from Annex A and the A-weighted octave-band sound pressure levels, $L_{p,\mathrm{A}f(k)i}$, from Table 2.

Table C.1 — A-weighted octave-band sound pressure levels, $L_{p,\mathrm{A}f(k)i}$, from Table 2

Values in decibels

	Octave-band centre frequency, *f* Hz						
	125	250	500	1 000	2 000	4 000	8 000
$L_{p,\mathrm{A}f(k)1}$	62,6	70,8	81,0	90,4	96,2	94,7	92,3
$L_{p,\mathrm{A}f(k)2}$	68,9	78,3	84,3	92,8	96,3	94,0	90,0
$L_{p,\mathrm{A}f(k)3}$	71,1	80,8	88,0	95,0	94,4	94,1	89,0
$L_{p,\mathrm{A}f(k)4}$	77,2	84,5	89,8	95,5	94,3	92,5	88,8
$L_{p,\mathrm{A}f(k)5}$	77,4	86,5	92,5	96,4	93,0	90,4	83,7
$L_{p,\mathrm{A}f(k)6}$	82,0	89,4	93,5	95,6	93,0	90,1	83,0
$L_{p,\mathrm{A}f(k)7}$	84,2	90,1	93,6	96,2	91,3	87,9	81,9
$L_{p,\mathrm{A}f(k)8}$	88,0	93,4	93,8	94,2	91,4	87,9	79,9

The eight PNR_{ji} values are calculated according to Formula (15) and H_j, M_j and L_j values are calculated according to Formulae (12), (13) and (14) for each subject *j*.

Table C.2 — PNR_{ji}, H_j, M_j and L_j values for each subject j

j	1	2	3	4	5	6	7	8
PNR_{j1}	26,9	33,3	31,3	25,2	27,8	26,2	24,6	33,1
PNR_{j2}	24,7	30,7	29,3	23,5	26,1	23,5	22,6	30,8
PNR_{j3}	22,7	28,5	27,5	22,0	24,4	21,1	21,0	28,7
PNR_{j4}	21,1	26,3	26,1	20,5	22,7	19,3	19,1	27,4
PNR_{j5}	19,8	24,6	24,6	19,3	21,0	17,7	17,7	26,2
PNR_{j6}	18,5	22,7	23,5	17,9	19,7	16,3	15,9	25,4
PNR_{j7}	17,6	21,8	22,8	17,0	19,0	15,5	15,0	24,5
PNR_{j8}	15,6	19,3	20,9	14,8	17,2	13,4	12,5	22,8
H_j	27,8	34,5	32,1	26,0	28,7	27,2	25,6	33,8
M_j	20,1	24,8	24,9	19,6	21,2	18,0	18,0	26,5
L_j	14,7	18,2	20,2	13,9	16,4	12,5	11,4	22,2
j	9	10	11	12	13	14	15	16
PNR_{j1}	22,6	26,2	32,3	21,0	32,0	21,4	33,1	35,5
PNR_{j2}	21,1	24,0	30,0	19,6	29,4	20,6	31,0	32,6
PNR_{j3}	19,6	22,2	28,0	18,3	27,3	20,3	29,3	30,5
PNR_{j4}	18,1	20,5	26,6	17,0	25,4	19,5	27,2	28,2
PNR_{j5}	16,6	19,1	25,2	15,7	24,0	18,9	25,9	26,8
PNR_{j6}	15,3	17,6	24,2	14,7	22,3	18,2	23,9	24,7
PNR_{j7}	14,6	16,8	23,4	14,1	21,3	17,6	22,9	23,6
PNR_{j8}	12,7	14,5	21,6	12,6	18,8	16,1	20,2	20,8
H_j	23,5	27,1	33,1	21,6	33,0	21,6	34,2	36,7
M_j	16,9	19,4	25,5	15,9	24,3	19,1	26,2	27,1
L_j	11,9	13,5	20,9	12,0	17,7	15,6	19,0	19,5

The H_m, M_m and L_m values are calculated according to Formulae (6), (7) and (8):

H_m = 29,2 dB

M_m = 21,7 dB

L_m = 16,2 dB

The H_s, M_s and L_s values are calculated according to Formulae (9), (10) and (11):

H_s = 4,8 dB

M_s = 3,8 dB

L_s = 3,5 dB

The H_{84}, M_{84} and L_{84} values are calculated according to Formulae (3), (4) and (5) with α = 1,00. The results are rounded to the nearest integer:

H_{84} = 24 dB

M_{84} = 18 dB

L_{84} = 13 dB

C.2 Use of H_{84}, M_{84} and L_{84} values to estimate $L'_{p,\mathrm{A84}}$ for a particular hearing protector in a specific noise situation

The effective A-weighted sound pressure level, $L'_{p,\mathrm{A84}}$, for a hearing protector with given H_{84}, M_{84} and L_{84} values (from C.1) and a specific noise situation can be estimated in two steps as follows:

a) The difference ($L_{p,\mathrm{C}}$ − $L_{p,\mathrm{A}}$) is calculated. Using the noise spectrum from Annex B gives ($L_{p,\mathrm{C}}$ − $L_{p,\mathrm{A}}$) = −1 dB. The predicted noise level reduction, PNR_{84}, is calculated using Formula (16) as follows:

$$PNR_{84} = 18\,\mathrm{dB} - \frac{24-18}{4}(103{,}0-104{,}0-2)\,\mathrm{dB} = 22{,}5\,\mathrm{dB}$$

b) The A-weighted sound pressure level, $L_{p,\mathrm{A}}$, of the noise spectrum from Annex B is equal to 104 dB. The effective A-weighted sound pressure level, $L'_{p,\mathrm{A84}}$, is calculated using Formula (18) as follows:

$L'_{p,\mathrm{A84}}$ = 104 dB – 22,5 dB = 81,5 dB

This value is rounded to the nearest integer. It can then be stated that the effective A-weighted sound pressure level will be less than or equal to 82 dB for 84 % of the individuals when the hearing protector is properly worn by various people in this noise environment.

The calculation example shown here is provided via an Excel-sheet at standards.iso.org/iso/4869/-2/ed-2/en as well, by which the user may carry out own calculations.

Annex D
(informative)

Example of the calculation and use of *SNR* values

D.1 Calculation of the *SNR* value for a particular hearing protector

In this example, a protection performance of 84 % is selected. Using the a_{jf} values from Annex A and the $L_{p,\mathrm{A}f(k)}$ values from Table 3 the *SNR* value is calculated.

Table D.1 — A-weighted octave-band sound pressure levels, $L_{p,\mathrm{A}f(k)}$, from Table 3

Values in decibels

	Octave-band centre frequency, *f* Hz						
	125	250	500	1 000	2 000	4 000	8 000
$L_{p,\mathrm{A}f(k)}$ from Table 3	75,9	83,4	88,8	92,0	93,2	93,0	90,9

The SNR_j values are calculated according to Formula (22) for each subject *j*.

Table D.2 — SNR*j* values for each subject *j*

Values in decibels

j	1	2	3	4	5	6	7	8
SNR_j	23,1	27,7	28,0	22,3	24,1	21,2	20,7	29,8
j	9	10	11	12	13	14	15	16
SNR_j	19,7	22,4	28,7	18,8	27,2	21,4	28,9	29,9

The SNR_m and SNR_s values are calculated according to Formulae (20) and (21):

$SNR_m = 24{,}6$ dB

$SNR_s = 3{,}9$ dB

The SNR_{84} value is calculated according to Formula (19) with $\alpha = 1{,}00$. The result is rounded to the nearest integer:

$SNR_{84} = 21$ dB

D.2 Use of the SNR_{84} value to estimate $L'_{p,\mathrm{A}84}$ for a particular hearing protector in a specific noise situation for which $L_{p,\mathrm{C}}$ is known

The effective A-weighted sound pressure level, $L'_{p,\mathrm{A}84}$, for a hearing protector with a given SNR_{84} (from D.1) can be estimated from the measured C-weighted sound pressure level of a specific noise. Using the noise spectrum from Annex B, gives $L_{p,\mathrm{C}} = 103$ dB.