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Ergonomics — Danger signals for public and work areas — Auditory danger signals

Ergonomie — Signaux de danger pour lieux publics et lieux de travail — Signaux de danger auditifs

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 7731 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 5, *Ergonomics of the physical environment*.

This second edition cancels and replaces the first edition (ISO 7731:1986), which has been technically revised.

Introduction

This International Standard specifies criteria applicable to the recognition of auditory danger signals, especially in cases where there is a high level of ambient noise. It covers auditory danger signals, desigated in the text of this standard by the use of the phrase “danger signals”, which apply to emergency signals and warning signals (see Table 1).

Auditory danger signals can also be found in the following International Standards:

— ISO 8201 dealing with emergency evacuation signals;

— ISO 11429 dealing with auditory and visual danger signals.

Various types of danger signals and their responses are described in Table 1.

It should be noted that ISO 11429 covers this subject in greater detail.

Table 1 — Various types of danger signals

Type of danger signal	Response
Auditory emergency evacuation signal	Leave the danger zone immediately
Auditory emergency signal	Take urgent action for rescue or protection
Auditory warning signal	Take preventative or preparatory action

Correctly designed signals can reliably call attention to a hazard or a dangerous situation, even when hearing protection is worn, without causing fright.

Ergonomics — Danger signals for public and work areas — Auditory danger signals

1 Scope

This International Standard specifies the physical principles of design, ergonomic requirements and the corresponding test methods for danger signals for public and work areas in the signal reception area and gives guidelines for the design of the signals. It may also be applied to other appropriate situations.

The relevance given in the definitions as to the difference between an auditory emergency signal, auditory emergency evacuation signal and an auditory warning signal should be noted. The emergency evacuation signal is covered in ISO 8201.

This International Standard does not apply to verbal danger warnings (e.g. shouts, loudspeaker announcements). ISO 9921 covers verbal danger signals.

Special regulations such as those for a public disaster and public transport are not affected by this International Standard.

2 Normative references

The following referenced documents are indispensable for the application 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.

IEC 61260, *Electroacoustics — Octave-band and fractional-octave-band filters*

3 Terms, definitions and symbols

For the purposes of this document, the following terms and definitions apply.

NOTE Definitions of symbols referred to in this International Standard are given in Annex A.

3.1
ambient noise
all sounds in the signal reception area not produced by the danger-signal transmitter

3.2
danger signals
depending on the degree of urgency and the possible effect of the danger on people, a distinction is made between three types of auditory danger signals: an auditory emergency signal, an auditory emergency evacuation signal and an auditory warning signal

3.2.1
auditory emergency signal
signal marking the onset and, if necessary, the duration and the end of a dangerous situation

3.2.2
auditory emergency evacuation signal
signal indicating the beginning or the actual occurrence of an emergency involving the possibility of injury and instructing the person(s) to immediately leave the danger zone in the recognized manner

NOTE The auditory emergency evacuation signal is the subject of ISO 8201.

3.2.3
auditory warning signal
signal indicating the possibility or actual occurrence of a dangerous situation requiring appropriate measures for the elimination or control of the danger

NOTE The auditory warning signal may also provide information concerning the conduct and courses of action to be taken.

3.3
effective masked threshold
level of auditory danger signal just audible over the ambient noise, taking account of the acoustic parameters of both the ambient noise in the signal reception area and the listening deficiencies (hearing protection, hearing loss and other masking effects)

3.4
octave
bandwidth of a filter which comprises a frequency range of a factor of two

NOTE That is to say, the cut-off frequency f_2 is twice the lower f_1 as specified in IEC 61260; e.g. for an octave-band centred on 500 Hz, the lower frequency is 353 Hz ($500/\sqrt{2}$), the upper frequency is 707 Hz ($500\sqrt{2}$).

3.5
1/3 octave
fractional-octave-band filter
bandwidth of a filter which comprises a frequency range of a factor of $\sqrt[3]{2}$

NOTE 1 That is to say, the cut-off frequency f_2 is $\sqrt[3]{2}$ times the lower f_1 (i.e. $f_2 = \sqrt[3]{2}\ f_1$ as specified in IEC 61260).

NOTE 2 A bandpass filter has a narrower frequency range than an octave filter. The octave filter can be subdivided into three 1/3 octave-bands.

3.6
reverberation time
time interval required for the sound-pressure level to decrease by 60 dB, after the emission by the source is stopped

3.7
signal reception area
area in which persons are intended to recognize and react to a signal

NOTE This International Standard does not deal with problems that might occur if the danger signals are heard from outside the signal reception area.

3.8
spectral content
overall frequency content of a signal, or of the ambient noise

4 Safety requirements

4.1 General

The nature of the danger signal shall be such that people in the reception area can hear and react to the signal as intended. If persons with hearing impairment (deafness) or hearing protection (helmets, ear plugs, etc.) are likely to be present, special care should be taken. The characteristics of the audible signal shall be adapted to take account of the characteristics relevant to the situation.

4.2 Recognition

4.2.1 Introduction

The reliable recognition of a danger signal requires that the signal be clearly audible, be sufficiently different from other sounds in the environment and have an unambiguous meaning.

In order of priority, any emergency evacuation signal shall take precedence over all other danger signals and danger signals shall take precedence over all other auditory signals.

4.2.2 Audibility

4.2.2.1 The danger signal shall be clearly audible. The effective masked threshold shall be distinctly exceeded. If relevant, the probability of hearing loss in the recipient population may be assessed and taken into account. If hearing protectors are worn, their levels of attenuation shall be known and introduced into the assessment.

To ensure its audibility, the A-weighted sound-pressure level of the danger signal shall not be lower than 65 dB at any position in the signal reception area.

In addition, at least one of the criteria in 4.2.2.2 to 4.2.2.4 shall be met.

4.2.2.2 For measurements of the A-weighted sound-pressure level [method a) in 5.2.2.1], the difference between the two A-weighted sound-pressure levels of the signal and the ambient noise shall be greater than 15 dB ($L_{\text{S, A}} - L_{\text{N, A}} > 15$ dB).

4.2.2.3 For measurements of the octave-band sound-pressure level [method b) in 5.2.3.1], the sound-pressure level of the signal in one or more octave-bands shall exceed the effective masked threshold by at least 10 dB in the octave-band under consideration ($L_{\text{S}i\text{, oct}} - L_{\text{T}i\text{, oct}} > 10$ dB).

4.2.2.4 For measurements of the 1/3 octave-band sound-pressure level [method c) in 5.2.3.2], the sound-pressure level of the signal in one or more 1/3 octave-bands shall exceed the effective masked threshold by 13 dB in the 1/3 octave-band under consideration ($L_{\text{S}i\text{, 1/3oct}} - L_{\text{T}i\text{, 1/3oct}} > 13$ dB).

4.2.3 Distinctiveness

Parameters of the danger signal (signal level, frequency spectrum, temporal pattern, etc.) shall be designed to stand out from all other sounds in the reception area and shall be distinctly different from any other signals. (See Clause 6.)

4.2.4 Unambiguity

The meaning of the danger signal shall be unambiguous.

4.2.5 Moving sources

The characteristics of a danger signal from a moving signal source shall be recognizable, regardless of the speed or movement direction of the source.

4.3 Review of the signal

The effectiveness of the danger signal shall be reviewed at both regular intervals and whenever a new signal (whether a danger signal or not) or a change in the ambient noise occurs, or any other relevant changes are made.

4.4 Recommended maximum level of the danger signal

If the A-weighted sound-pressure level of the ambient noise in the signal reception area exceeds 100 dB, the use of additional visual, rather than solely auditory, danger signals is recommended (e.g. visual danger signals according to ISO 11428 and ISO 11429). In any case, the maximum signal level should not exceed 118 dB(A) in the signal reception area.

5 Test methods

5.1 Measurement equipment

Measurements should be made with equipment conforming to IEC 61672 and IEC 61260.

For measuring the ambient noise and the signal, the maximum reading with time weighting “Slow” shall be used. Calculations shall be based on the samples taken from a representative number of measurements.

5.2 Objective acoustic measurements

5.2.1 General

Compliance with the following requirements shall be adequate for the auditory danger signal. (See 4.2.2.)

5.2.2 Weighted measurements

5.2.2.1 A-weighted measurements [method a)]

Measure the A-weighted sound-pressure level of the ambient noise ($L_{\mathrm{N, A}}$).

Measure the A-weighted sound-pressure level of the danger signal ($L_{\mathrm{S, A}}$).

Calculate $L_{\mathrm{S, A}} - L_{\mathrm{N, A}}$ and check compliance with the requirements given in 4.2.2.2.

5.2.3 Measurements made in the frequency domain

5.2.3.1 Octave-band measurements [method b)]

Measure the octave-band sound-pressure levels of the ambient noise ($L_{\mathrm{N}i,\ \mathrm{oct}}$).

Determine the effective masked threshold ($L_{\mathrm{T}i,\ \mathrm{oct}}$), according to Annex B.

Measure the octave-band sound-pressure levels of the danger signal ($L_{\mathrm{S}i,\ \mathrm{oct}}$).

Calculate ($L_{\mathrm{S}i,\ \mathrm{oct}} - L_{\mathrm{T}i,\ \mathrm{oct}}$) and check compliance with the requirements given in 4.2.2.3.

5.2.3.2 Third octave-band measurements [method c)]

Measure the 1/3 octave-band sound-pressure levels of the ambient noise ($L_{\mathrm{N}i,\ 1/3\mathrm{oct}}$).

Calculate the effective masked threshold ($L_{\mathrm{T}i,\ 1/3\mathrm{oct}}$), according to Annex B.

Measure the 1/3 octave-band sound-pressure levels of the danger signal ($L_{\mathrm{S}i,\ 1/3\,\mathrm{oct}}$).

Calculate ($L_{\mathrm{S}i,\ 1/3\,\mathrm{oct}} - L_{\mathrm{T}i,\ 1/3\,\mathrm{oct}}$) and check compliance with the requirements given in 4.2.2.4.

NOTE 1 By using methods b) or c), the difference between the signal-to-noise ratios can be smaller than in 5.2.2.1, method a).

NOTE 2 Methods b) and c) require more sophisticated measurement efforts.

NOTE 3 All other criteria according to Clause 6 also apply to the methods of measurement.

5.2.4 Measurement of the auditory signal with ambient noise present

Generally, the auditory signal is measured with the ambient noise absent, i.e. the source of ambient noise (e.g. machinery) shall be switched off during the measurement. If this is not possible (permanent ambient noise which would be measured along with the auditory signal), alternative methods of measurement should be employed, taking into account reduced accuracy.

5.3 Subjective test method

It is preferable to carry out objective acoustic measurements. In their absence, a subjective listening test may be used.

Details of the method for a listening test shall comply with Annex C.

6 Design criteria for auditory danger signals

6.1 General

When designing auditory danger signals the following are relevant:

- the sound-pressure level;
- spectral characteristics;
- temporal characteristics.

6.2 Sound-pressure level

Danger signals are deemed to be clearly audible in the signal reception area if their A-weighted sound-pressure levels exceed the sound-pressure level of ambient noise by 15 dB or more (4.2.2.2) and if the A-weighted sound-pressure level of the signal is not lower than 65 dB (4.2.2.1). Together, these two requirements are sufficient but not always necessary for unfailing recognition. If the frequency and/or the temporal distribution of the danger signal clearly differ from the corresponding characteristics of the ambient noise, a lower sound-pressure level of the signal may be sufficient. This level, however, shall comply with that specified in 4.2.2.

The maximum sound-pressure level of the danger signal should be designed so that the signal is clearly audible. Reactions due to fright (e.g. more than 30 dB in 0,5 s) may be caused by using too high a sound-pressure level. Fright may also be expected whenever there is an unexpected steep increase in the sound-pressure level.

6.3 Spectral characteristics

The danger signal should include frequency components in the 500 Hz to 2 500 Hz frequency range. However, generally two dominant components from 500 Hz to 1 500 Hz are recommended.

NOTE 1 The more the centre frequency of the octave-band, where the danger signal is highest in level, differs from the centre frequency of the octave-band where the ambient noise is highest in level, the easier it is to recognize the danger signal.

In the case of persons wearing hearing protection or having a hearing loss, sufficient signal energy should be present in the frequency range below 1 500 Hz (see Example D.6 in Annex D).

NOTE 2 Due to the internal masking of the hearing organ, low-frequency components of the ambient noise may mask higher frequency components of the danger signal (see Figure D.5). Hearing loss can also show an effect that may be additional to the masking effect.

6.4 Temporal characteristics

6.4.1 Temporal distribution of the danger signal

In general, pulsating danger signals should be preferred to the signals that are constant in time. The repetition frequencies shall be in the range from 0,5 Hz to 4 Hz. The pulse duration and the pulse repetition frequency of the danger signal shall not be identical with the pulse duration and the pulse repetition frequency of any periodically varying ambient noise in the signal reception area.

When higher pulse repetition frequencies coincide with a long reverberation time in the signal reception area, the pulsation will be smoothed out. Hence, discrimination between signals with similar frequency, but different pulse repetition frequencies, will decrease.

Table 2 gives the maximum repetition frequency appropriate in the signal reception area for different reverberation times.

Table 2 — Maximum repetition frequency for four different reverberation times, t

Maximum repetition frequency Hz	t s
0,5	8
1	4
2	2
4	1

The audible emergency evacuation signal (ISO 8201) is a special danger signal. All other audible danger signals should differ significantly in their temporal pattern from the audible emergency evacuation signal.

6.4.2 Temporal distribution of the frequencies

In general, danger signals with varying fundamental frequencies should be selected.

For example, danger signals with a fundamental frequency sweep in the range of 500 Hz to 1 000 Hz, with four harmonics, will give adequate signal audibility.

6.4.3 Duration of the danger signals

Temporary masking of the danger signal by ambient noise may be permitted in certain cases, for example, if there are short time variations of the ambient noise. However, in such cases, care shall be taken to ensure that, not later than 1 s after the signal has started, the danger signal complies with the requirements of 4.1 and 4.2 for a period of at least 2 s. The temporal characteristics of the danger signal should depend on the duration and type of the danger.

6.5 Information required from suppliers

Manufacturers and agents of sound sources for danger signals shall present at least the following information in their data sheets:

a) the minimum and maximum values of the A-weighted sound-power level ($L_{W,\ A}$) or, if not available, the A-weighted sound-pressure level ($L_{S,\ A}$) measured in the free field at a distance of 1 m from the sound source in the main direction of radiation;

b) spectral components, by octave or 1/3 octave, in the centre frequencies from 125 Hz to 8 000 Hz at a distance of 1 m from the sound source in the main direction of radiation;

c) the temporal envelope of the danger signal for a representative time period.

Annex A
(normative)

Definitions of symbols

d_i: sound attenuation of the hearing protectors, in decibels (dB) in the octave-band i

f: centre frequency of a frequency band (e.g. octave-band)

$L_{\mathrm{N}i,\ \mathrm{oct}}$: level in octave-band i of the ambient noise, in decibels (dB) (ref. 20 µPa)

$L_{\mathrm{N}i,\ 1/3\,\mathrm{oct}}$: level in 1/3 octave-band i of ambient noise, in decibels (dB) (ref. 20 µPa)

$L_{\mathrm{N,\ A}}$: A-weighted level of ambient noise, in decibels (dB) (ref. 20 µPa)

$L_{\mathrm{S,\ A}}$: A-weighted sound level of auditory danger signal, in decibels (dB) (ref. 20 µPa)

$L_{\mathrm{S}i,\ \mathrm{oct}}$: level in octave-band i of auditory danger signal, in decibels (dB) (ref. 20 µPa)

$L_{\mathrm{T}i,\ \mathrm{oct}}$: level in octave-band i of masked threshold, in decibels (dB) (ref. 20 µPa)

$L_{\mathrm{S}i,\ 1/3\,\mathrm{oct}}$: level in 1/3 octave-band i of auditory danger signal, in decibels (dB) (ref. 20 µPa)

$L_{\mathrm{T}i,\ 1/3\,\mathrm{oct}}$: level in 1/3 octave-band i of masked threshold, in decibels (dB) (ref. 20 µPa)

$L_{\mathrm{W,\ A}}$: A-weighted sound-power level of the auditory danger signal, in decibels (dB) (ref. 1 pW)

Annex B
(normative)

Calculation of effective masked threshold

B.1 Introduction

The effective masked threshold can be approximated from either the octave-band or the 1/3 octave-band levels of the ambient noise.

B.2 Octave-band analysis

The effective masked threshold $L_{\mathrm{T}i,\ \mathrm{oct}}$ for octave-band analysis is calculated by the following procedure.

Step 1: in the lowest octave-band, i = 1

$$L_{\mathrm{T1,\ oct}} = L_{\mathrm{N1,\ oct}}$$

Step i: ($i > 1$)

$$L_{\mathrm{T}i,\ \mathrm{oct}} = \max.\ (L_{\mathrm{N}i,\ \mathrm{oct}}, L_{\mathrm{T}(i-1)\ \mathrm{oct}} - 7{,}5\ \mathrm{dB})$$

Repeat step i for i = 2 ... up to the highest octave-band.

B.3 1/3 Octave-band analysis

The effective masked threshold $L_{\mathrm{T}i,\ 1/3\,\mathrm{oct}}$ for 1/3 octave-band analysis is calculated by the following procedure.

Step 1: in the lowest 1/3 octave-band, i = 1

$$L_{\mathrm{T}i,\ 1/3\,\mathrm{oct}} = L_{\mathrm{N}i,\ 1/3\,\mathrm{oct}}$$

Step i: ($i > 1$)

$$L_{\mathrm{T}i,1/3\,\mathrm{oct}} = \max.\ (L_{\mathrm{N}i,\ 1/3\,\mathrm{oct}}, L_{\mathrm{T}(i-1),1/3\,\mathrm{oct}} - 2{,}5\ \mathrm{dB})$$

Repeat step i for i = 2 ... up to the highest 1/3 octave-band.

NOTE 1 This International Standard takes account of moderate degrees of hearing impairment by

a) incorporating a suitable correction for masking,

b) specifying a minimal level of A-weighted signal, or

c) avoiding signals at high frequency.

Nevertheless, some individuals with extreme hearing impairment may not hear the signal.

NOTE 2 This method may be applied when hearing protectors are being worn, by reducing, in every frequency band, the levels of noise and signal by the relevant mean sound attenuation of the hearing protector (see Example D.6). After calculation of the effective threshold under the protector, the calculated levels may be increased in every frequency band by adding the attenuation values to obtain the effective masked threshold outside the protector.

Annex C
(normative)

Listening test

In the absence of an objective acoustic measurement for checking the audibility of a danger signal, a listening test shall be made. To carry out a listening test in any signal reception area, the following procedure shall be used:

Form a representative group including at least 10 subjects from the signal reception area. Test subjects shall wear their own personal protection devices used in the operating mode.

If there are less than 10 persons in the signal reception area, the tests shall be made for all the persons, under representative conditions.

Tests shall be made without prior notice. Present the danger signal during the most unfavourable auditory conditions in that reception area (i.e. at the time of highest level of ambient noise, and possibly during the occurrence of other signals). This test shall be repeated on at least five occasions. The test shall be carried out using the subjects on an individual basis, eliminating influences from within a group if possible.

Each test subject will be asked to rate the audibility of the signal from the following two alternatives:

— clearly audible;

— not clearly audible.

The signal audibility shall be deemed adequate if 100 % of the participants confirm that, on all five occasions, the signal is clearly audible.

Annex D
(informative)

Examples of danger signals

D.1 Introduction

In the following examples, continuous lines are used for the danger-signal spectra (L_S), dashed lines for the ambient-noise spectra (L_N), and dotted lines for the effective masked threshold (L_T) where it differs from the noise spectrum.

D.2 Example 1: Danger signal indicating approaching shuttle conveyer

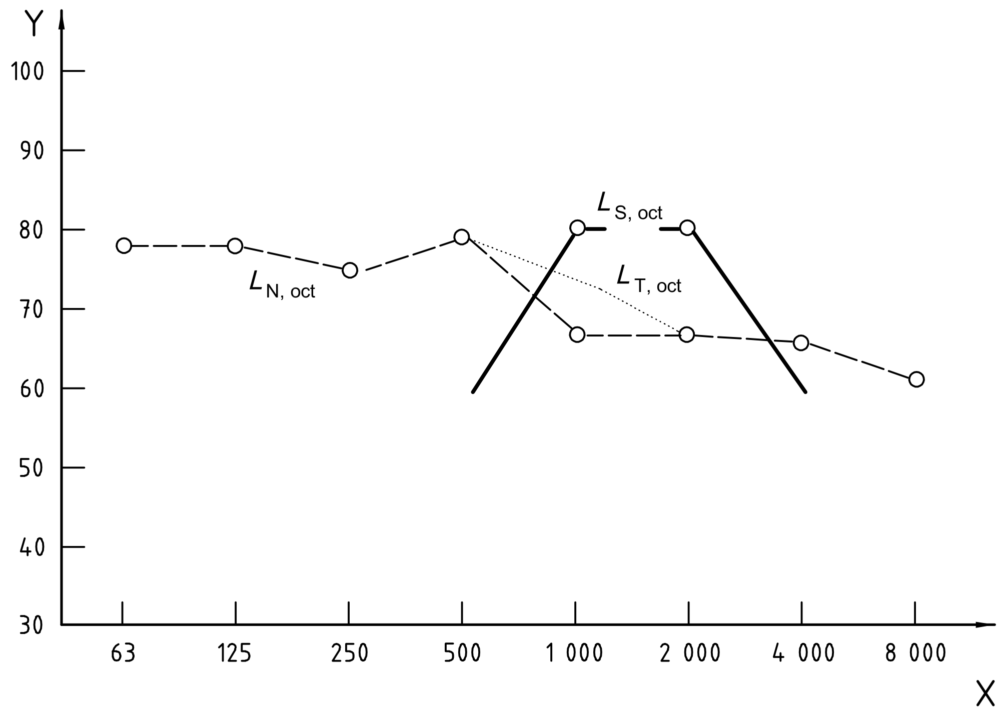
Ambient noise within the signal reception area: sound-insulated axial flow fan.

Characteristics of the ambient noise: constant in time.

Level of A-weighted ambient noise: $L_{N, A}$ = 78 dB (A).

Selected auditory danger signal: $L_{S, A}$ = 84 dB (A).

Characteristics of the danger signal, electroacoustically generated, intermittent signal duration: on = 1 s, off = 1 s.



Key

X octave-band centre frequency (Hz)

Y octave-band level, L_{oct} (dB)

Figure D.1 — Graph displaying octave-band analysis of the ambient noise, the effective masked threshold and of the danger signal during the "on" period

The frequency distribution and the temporal distribution of the danger signal and of the ambient noise clearly differ from each other. The danger signal is within a frequency range of good audibility. The effective masked threshold is exceeded by more than 10 dB in the octave-band 2 000 Hz. The danger signal can thus be easily heard and recognized.

D.3 Example 2: Danger signal indicating lack of oil in rolling mill

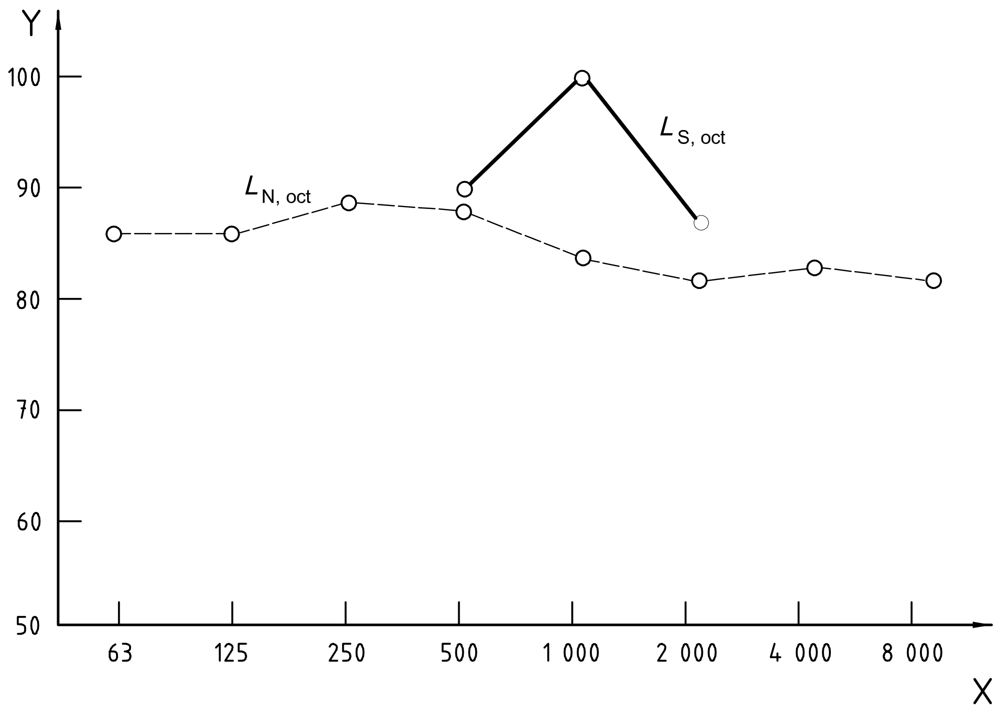
Ambient noise within the signal reception area: annealing furnaces, rolling mill, removal of scale by means of compressed air.

Characteristics of the ambient noise: constant in time.

Level of ambient noise: $L_{N, A}$ = 89 dB (A).

Selected auditory danger signal: $L_{S, A}$ = 100 dB (A).

Characteristics of the danger signal: horn (continuous signal), comparable signals do not occur within the signal reception area.



Key

X octave-band centre frequency (Hz)

Y octave-band level, L_{oct} (dB)

Figure D.2 — Graph displaying octave-band analysis of the ambient noise (equal to the effective masked threshold) and of the danger signal

The danger signal exceeds the ambient noise by more than 10 dB within one octave-band; the danger signal can thus be easily recognized using the octave-band method (5.2.3.1) but in 4.2.2.2, the signal would be rejected because the difference between the two A-weighted sound-pressure levels is less than 15 dB (A).

D.4 Example 3: Danger signal indicating approaching crane

Ambient noise within the signal reception area:

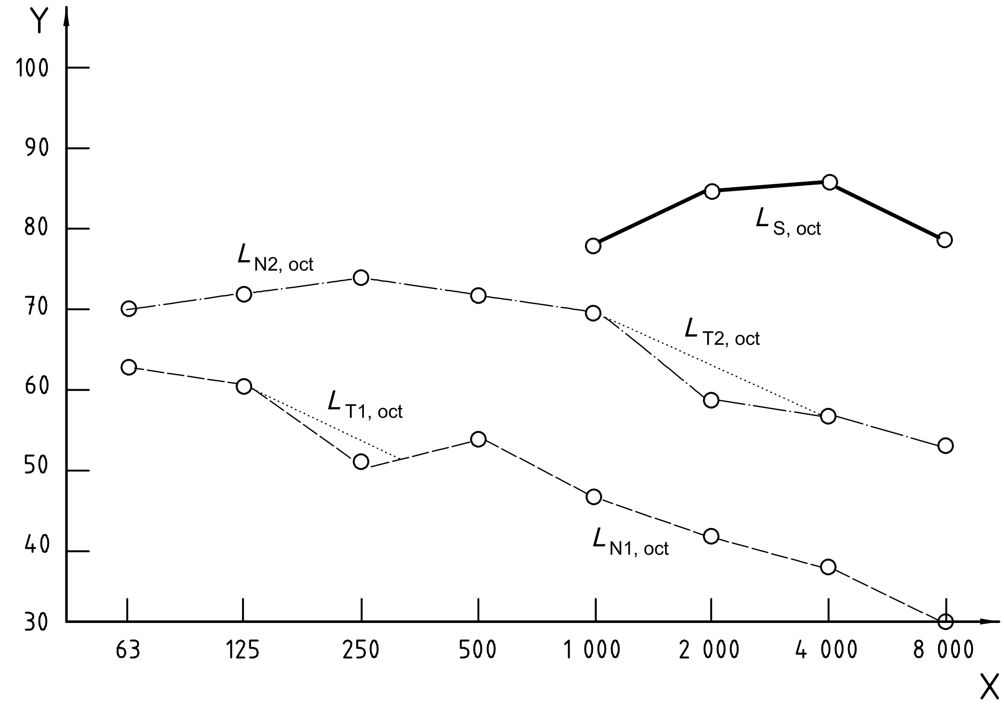
a) basic traffic noise: $L_{N1, A}$ = 54 dB (A);

b) crane noise: $L_{N2, A}$ = 74 dB (A).

Characteristics of noise: both varying in time, therefore the A-weighted sound level as well as the octave-band level have been set as maximum values using time weighting “Slow”.

Selected danger signal: $L_{S, A}$ = 90 dB (A).

Characteristics of the danger signal: ringing bell with low repetition frequency.



Key

X octave-band centre frequency (Hz)

Y octave-band level, L_{oct} (dB)

Figure D.3 — Graph displaying octave-band analysis of the basic traffic and crane noise, the effective masked threshold and of the danger signal

The danger signal exceeds the ambient noise in the A-weighted sound level by more than 15 dB and is in a totally different range of frequencies. It can thus be easily recognized.

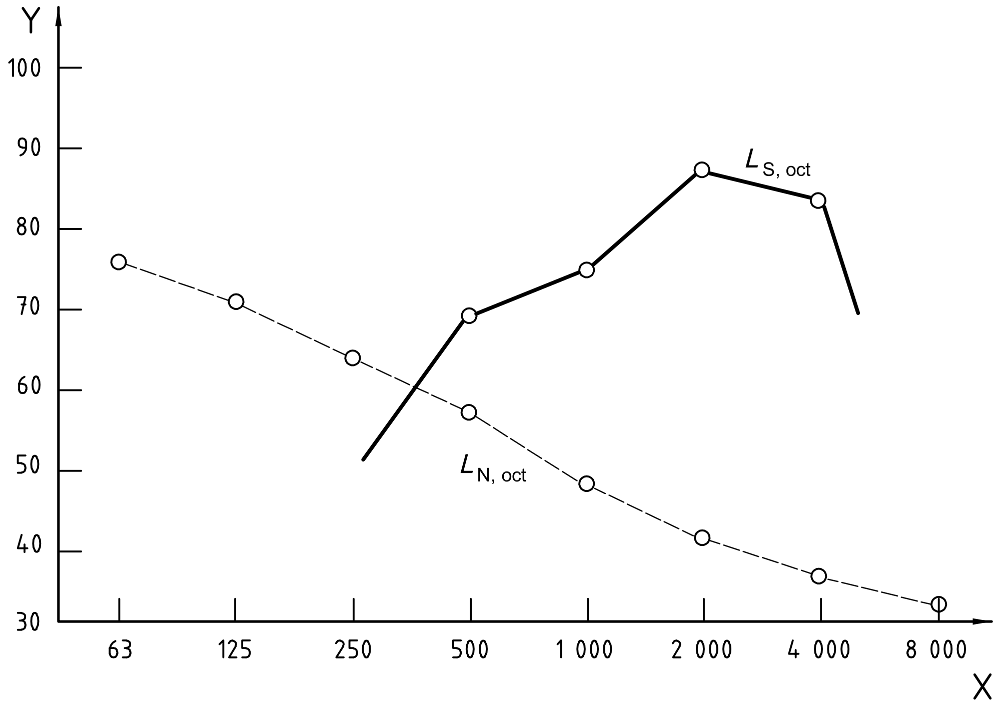
D.5 Example 4: Danger signal used in the area of a conveyor

Ambient noise within the signal reception area (operator's cabin): $L_{N, A}$ = 59 dB (A).

Characteristics of the ambient noise: only slight variations during operation.

Selected danger signal: $L_{S, A}$ = 90 dB (A)

Characteristics of the danger signal: bell with high repetition frequency.



Key

X octave-band centre frequency (Hz)

Y octave-band level, L_{oct} (dB)

Figure D.4 — Graph displaying octave-band analysis of ambient noise (equal to the effective masked threshold) and of the danger signal

Because of the frequencies involved, the difference in noise levels between the danger signal and the ambient noise, and their different temporal distributions, the danger signal can be easily recognized, on condition that there are no other major noise sources. The difference between $L_{N, A}$ and $L_{S, A}$ is greater than recommended in 6.2, thus the signal level should be reduced by 10 dB because of the possibility of fright.

D.6 Example 5: Danger signal indicating approach of a railway-track-ballast cleaning apparatus within an industrial plant

Ambient noise in the signal reception area: $L_{N, A}$ = 94 dB (A).

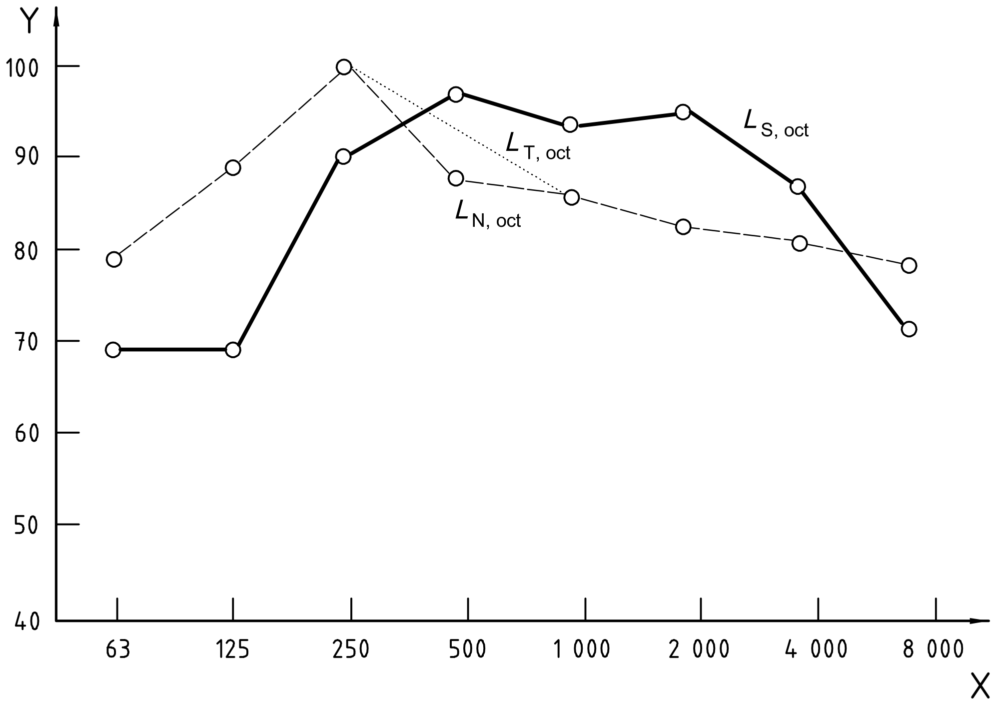
Selected danger signal: $L_{S, A}$ = 100 dB (A).

Characteristics of the danger signal:

— horn signal;

— basic frequency in the 250 Hz band;

— duration of each pulse approximately 2 s.



Key

X octave-band centre frequency (Hz)

Y octave-band level, L_{oct} (dB)

Figure D.5 — Graph displaying octave-band analysis of the ambient noise, the effective masked threshold and the danger signal during the "on" period

The frequency distribution and the temporal distribution of the danger signal and the ambient noise clearly differ from each other. The effective masked threshold is exceeded by more than 10 dB over two octaves (1 000 Hz and 2 000 Hz). The danger signal can thus be easily recognized.

D.7 Example 6: Danger signal of Example 5, when a hearing protector is worn

An appropriate hearing protector for the given ambient noise and horn signal shows a flat attenuation curve.

Mean attenuation values, d_i, are given in Table D.1.

Table D.1 — Mean attenuation values

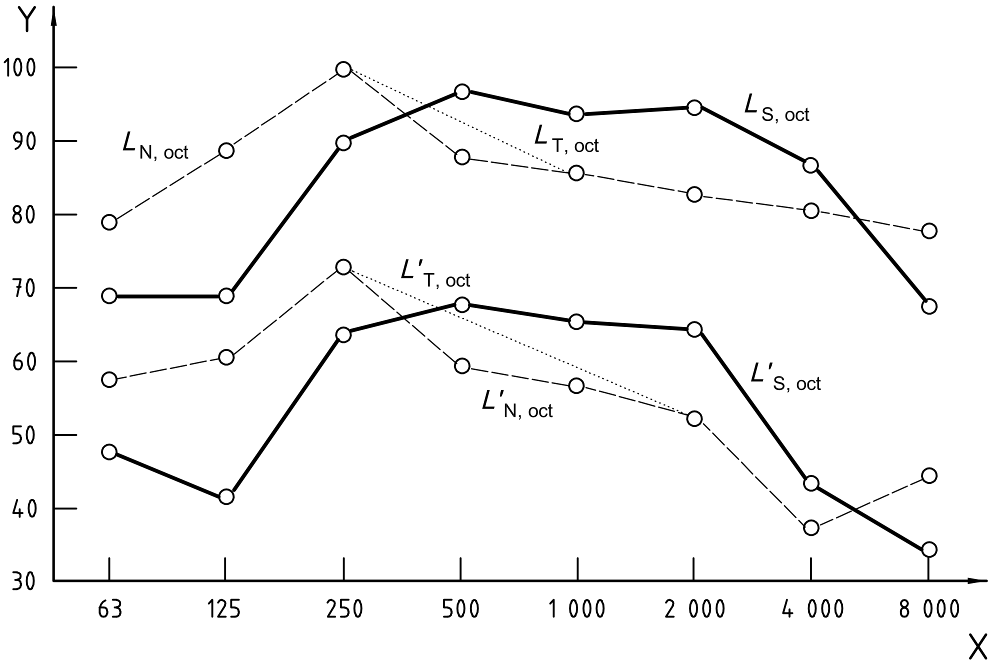
f (Hz) (octave-band)	63	125	250	500	1 000	2 000	4 000	8 000
d_i, (dB)	21	27	26	28	29	30	43	33

Calculation of the effective octave-band levels under the hearing protector, where

$L'_{\text{N, oct}}$ is the calculated effective octave-band level of the ambient noise $L_{\text{N, oct}} - d_i$;

$L'_{\text{S, oct}}$ is the calculated effective octave-band level of the auditory danger signal $L_{\text{S, oct}} - d_i$;

$L'_{\text{T, oct}}$ is the octave-band level of masked threshold under the hearing protector.



Key

X octave-band centre frequency (Hz)

Y octave-band level, L_{oct} (dB)

Figure D.6 — Graph displaying octave-band analysis of the ambient noise, the effective masked threshold and the danger signal (above) and the effective levels under the hearing protector (below)

The masked threshold $L_{T,\ oct}$ is exceeded by 12 dB in the 2 kHz octave-band. The danger signal can be easily recognized even by persons wearing the hearing protector.

Bibliography

[1] ISO 266, *Acoustics — Preferred frequencies*

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

[3] ISO 8201, *Acoustics — Audible emergency evacuation signal*

[4] ISO 9921, *Ergonomics — Assessment of speech communication*

[5] ISO 11428, *Ergonomics — Visual danger signals — General requirements, design and testing*

[6] ISO 11429, *Ergonomics — System of auditory and visual danger and information signals*

[7] IEC 60268-16, *Sound system equipment — Part 16: Objective rating of speech intelligibility by speech transmission index*

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

[9] IEC 61672-2, *Electroacoustics — Sound level meters — Part 2: Pattern evaluation tests*

[10] IEC 60849, *Sound systems for emergency purposes*

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