SLOVENSKI STANDARD
SIST EN 457:1998

01-november-1998

Varnost strojev - Sliġni nevarnostni signali - Sploġne zahteve, naļ rtovanje in preskuġanje (ISO 7731:1986, modificiran)

Safety of machinery - Auditory danger signals - General requirements, design and testing (ISO 7731:1986, modified)

Sicherheit von Maschinen - Akustische Gefahrensignale - Allgemeine Anforderungen, Gestaltung und Prüfung (ISO 7731:1986, modifiziert)

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Sécurité des machines - Signaux auditifs de danger - Exigences générales, conception et essais (ISO 7731:1986, modifiée)

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Ta slovenski standard je istoveten z: **EN 457:1992**

ICS:

13.110	Varnost strojev	Safety of machinery

SIST EN 457:1998 **en**

2003-01.Slovenski inštitut za standardizacijo. Razmnoževanje celote ali delov tega standarda ni dovoljeno.

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EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 457

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Descriptors: Human factors engineering, work safety, accident prevention, work room, hazardous areas, signalling, acoustic signals, audibility, auditory threshold, design, safety requirements, tests

English version

Safety of machinery — Auditory danger signals — General requirements, design and testing

(ISO 7731:1986 modified)

Sécurité des machines — Signaux auditifs de danger — Exigences générales, conception et essais
(ISO 7731:1986 modifiée)

Sicherheit von Maschinen — Akustische Gefahrensignale — Allgemeine Anforderungen, Gestaltung und Prüfung
(ISO 7731:1986 modifiziert)

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

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Foreword

At its second meeting in June 1988 CEN/TC 122 "Ergonomics" decided to transform the International Standard ISO 7731 "Danger signals for work places — Auditory danger signals" into a European Standard. The respective Questionnaire Procedure (PQ) was carried out in February 1989.

Due to the positive voting result the Technical Bureau (CEN/BT) decided at its meeting in November 1989 to proceed to formal vote for adoption of the International Standard as EN 27731.

At its first meeting in April 1990 the newly created working group CEN/TC 122/WG 8 "Danger signals and speech communication in noisy environments" decided that ISO 7731 should be slightly modified due to the PQ comments and the necessity for explanation regarding the relationship between this European Standard and the EC Directive on Machinery Safety (89/392/EEC) as well as EN 292 on the safety of machinery.

According to the Common CEN/CENELEC Rules, being part of the Internal Regulations of CEN, the following countries are bound to implement this European Standard: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

As requested by CEN/TC 122 working group CEN/TC 122/WG 8 has prepared the modifications at its meeting on 9th and 10th of April 1990.

The text of the International Standard ISO 7731:1986 was approved by CEN as a European Standard with agreed common modifications as given below.

a) The title was changed in order to indicate the relationship with the safety of machinery.

b) The scope was modified in order to indicate the relationship with EN 292-2.

c) The reference to ISO 8201 "Acoustics — Audible emergency evacuation signal" was replaced by a general reference to a European Standard being under preparation.

d) The numbering of clause **8.5** was changed into **9** in order to separate the required information on sound sources from the guidelines for the design of auditory danger signals.

e) A new paragraph c) was added to clause **9**.

f) An example for the calculation of the effective masked threshold was added as informative annex A; the original annex became informative annex B.

g) Changes of editorial nature were made.

The common modifications mentioned above are indicated by a vertical line in the margin.

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0 Introduction

This standard has been prepared to obtain a harmonized standard in the sense of the Machinery Directive and associated EFTA regulations.

This European Standard defines criteria applicable to the recognition of sound danger signals in the signal reception area especially in cases where there is a high level of ambient noise.

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

1 Scope

This European Standard specifies the safety and ergonomic requirements and the corresponding test methods for auditory danger signals and gives guidelines for the design of the signal to be clearly perceived and differentiated as required in **5.3** of EN 292-2.

This European Standard does not apply to verbal danger warnings (e.g. shouts, loudspeaker announcements).

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

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 292-2:1991, *Safety of machinery; Basic concepts, general principles for design; Technical principles and specifications.*

ISO 266, *Acoustics — Preferred frequencies for measurements.*

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

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

IEC 651, *Sound level meters.*

3 Definitions

For the purpose of this European Standard the following definitions apply.

3.1
auditory danger signal

an auditory signal indicating the onset and, if necessary, the duration and the end of a dangerous situation

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

3.1.1
auditory warning signal (including prestart warning signals)

signal indicating the possibility or actual occurrence of a dangerous situation requiring appropriate measures for the elimination or control of the danger and indications concerning the conduct and course of action to be taken

3.1.2
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 leave the danger zone in the recognized manner

NOTE A European Standard on auditory emergency evacuation signal is under preparation.

3.2
signal reception area

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

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

3.3
ambient noise

any sound in the signal reception area not produced by the danger signal transmitter

3.4
masked threshold (effective threshold of audibility in noise)

the level of sound at which the auditory danger signal is just audible in ambient noise taking into account the heating deficiencies of the listeners as well as the attenuation of heating protectors

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4 Symbols

f:	centre frequency of a frequency band (e.g. 1/3 octave band)
$L_{W,\,A}$:	A-weighted sound power level of the auditory danger signal in dB
d:	sound attenuation of the hearing protectors in dB
$L_{T,\,oct}$:	octave level of masked threshold in dB
$L_{T,\,1/3\,oct}$:	1/3 octave level of masked threshold in dB

Sound pressure levels:

L_{oct}:	octave band level (Reference: 20μPa)
$L_{N,\,A}$:	A-weighted level of ambient noise in dB
$L_{N,\,oct}$:	octave level of ambient noise in dB
$L_{N,\,1/3\,oct}$:	1/3 octave level of ambient noise in dB
$L_{S,\,A}$:	A-weighted sound level of auditory danger signal in dB
$L_{S,\,oct}$:	octave level of auditory danger signal in dB

5 Safety requirements

5.1 General

The nature of the auditory danger signal shall be such that any person in the signal reception area can recognize and react to the signal as intended.

Auditory danger signals shall take precedence concerning recognition over all other auditory signals.

An auditory emergency evacuation signal shall take precedence concerning recognition over all auditory warning signals.

Care shall be taken to review the effectiveness of the auditory danger signal at regular intervals and whenever a new signal (whether a warning signal or not), or noise, is introduced.

5.2 Recognition

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

5.2.1 *Audibility*

The signal sound has to be clearly audible. The masked threshold shall be exceeded. Usually this can be achieved if the A-weighted sound level of the signal exceeds the level of ambient noise by 15 dB or more.

More accurate predictions can be obtained by the use of octave band analysis or 1/3 octave band analysis.

NOTE The use of 1/3 octave band analysis gives more precise results, but in most cases octave band analysis is sufficient.

When using octave band analysis the sound level shall exceed the masked threshold by at least 10 dB in one octave band or more in the frequency range given in **8.2**.

When using 1/3 octave band analysis the sound level shall exceed the masked threshold by at least 13 dB in one 1/3 octave band or more in the frequency range given in **8.2**.

In all cases, the hearing ability of the recipient population and the use of hearing protectors should be taken into account.

Unless there is direct evidence to the contrary, e.g. results of the listening check (see **6.2**), the A-weighted sound level of the signal shall be not less than 65 dB to ensure its audibility amongst recipients with normal hearing or mild hearing loss. Where recipients have moderate or severe hearing losses a listening check shall be carried out including a representative sample of these persons, or reliance should not be placed on recognition of the danger signal.

5.2.2 *Discriminability*

At least two of the acoustic parameters of danger signals (sound level, temporal distribution, combination of frequencies) which influence discriminability of the signals shall be in a dominant way different from those of other signals in the signal reception area and from the ambient noise.

5.2.3 *Unambiguity*

The meaning of the auditory danger signal shall be unambiguous. Auditory danger signals and signals serving other purposes shall not be similar.

Auditory danger signals from mobile sources of danger shall be generated so as to be audible and recognizable regardless of the speed or number of revolutions of the source.

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6 Test methods

6.1 Acoustic measurements

Compliance with the requirements of **5.2** can be checked using measuring equipment; this requires:

a) measurement of the A-weighted sound levels of the ambient noise and the signals [these may already be sufficient if the difference between the sound levels is greater than 15 dB (see **8.1**)];

b) frequency analysis, if by measurement of the A-weighted sound levels no valid statements can be made;

c) measurements of the temporal distribution of the A-weighted sound levels of the auditory danger signal.

Measurements should be made by equipment conforming to ISO 266, IEC 225 and IEC 651 (sound level meters class 2 or better).

For measuring the ambient noise, time weighting "Slow" is to be preferred. In cases of fluctuating noise the maximum value should be taken into consideration.

6.2 Listening check

The auditory danger signal requirements given in **5.2** are also deemed to be complied with if the persons present in the signal reception area recognize the auditory danger signal.

To make a listening check at, for example, the work place, the following procedure may be used:

Form a group of at least 10 test subjects from the signal reception area representing, as far as possible, all age groups present.

Without previous notice, present the auditory danger signal to this group during the most unfavourable situation in the signal reception area (i.e. at the highest level of ambient noise, and possibly during the occurrence of other signals). The test shall be repeated five times.

If necessary, test subjects shall use their own personal noise protection devices. The auditory danger signal is deemed discriminable if it is recognized by all test subjects. If there are less than ten persons in the signal reception area, the tests shall be made in the presence of all the persons.

Older persons and persons with hearing impairment in the signal reception area shall be included in the group of test subjects for the listening check.

7 Calculation of effective masked threshold

The masked threshold can be approximated from the octave band levels $L_{N_n,\ \mathrm{oct}}$ or 1/3 octave band levels $L_{N_n,\ 1/3\ \mathrm{oct}}$ of the ambient noise in the frequency band n.

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

Step 1: In the lowest octave band "1"

$$L_{T_1,\ oct} = L_{N_1,\ \mathrm{oct}}$$

Step n: ($n > 1$)

$$L_{T_n,\ \mathrm{oct}} =$$

$$\max.\ (L_{N_n,\ \mathrm{oct}};\ L_{T_{n-1},\ \mathrm{oct}} - 7{,}5\ \mathrm{dB})$$

Repeat step n for $n = 2$ ... up to the highest octave band.

NOTE 1 An example for calculation is given in annex A.

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

Step 1: In the lowest 1/3 octave band "1"

$$L_{T_1\ 1/3} = L_{N_1,\ 1/3\ \mathrm{oct}}$$

Step n: ($n < 1$)

$$L_{T_n,\ 1/3\ \mathrm{oct}} =$$

$$\max.\ (L_{N_n\ 1/3\ \mathrm{oct}};\ L_{T_{n-1},}\ L_{T_{n-1},\ 1/3\ \mathrm{oct}} - 2{,}5\ \mathrm{dB})$$

Repeat step n for $n = 2$ ... up to the highest 1/3 octave band.

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 6 in annex B).

8 Guidelines for the design of auditory danger signals

The following guidelines should be observed when designing auditory danger signals.

8.1 Sound pressure level

Auditory danger signals are usually clearly audible if their A-weighted sound levels exceed the level of ambient noise by 15 dB or more and the A-weighted level of the signal is equal to or greater than 65 dB. This condition is usually sufficient (see **5.2.1**) but not always necessary for unfailing recognition. If the frequency and/or the temporal distribution of the auditory 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 be not less than that specified in **5.2.1**.

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The sound level of the auditory danger signal should be set so that the signal is clearly recognizable but reactions due to fright are considerably reduced after the sounding of the signal. Reactions due to fright may be expected whenever there is an unexpected steep increase in the sound level (e.g. more than 30 dB in 0,5 s).

If the A-weighted sound level of the ambient noise in the signal reception area exceeds 110 dB the use of additional, rather than solely auditory, danger signals is recommended (e.g. visual danger signals).

8.2 Frequencies

The auditory danger signal should be based on frequencies in the 300 to 3 000 Hz range. The more the centre frequency of the octave band where the danger signal is the highest differs from the centre frequency of the octave band where the ambient noise is the highest, the easier it is to recognize the danger signal. The auditory danger signal shall have sufficient energy in the frequency range below 1 500 Hz to meet the needs of persons with hearing loss or wearing hearing protectors (see **5.2.1**).

8.3 Temporal characteristics

8.3.1 *Temporal distribution of the sound level*

In general, pulsating auditory danger signals should be preferred to signals that are constant in time. The pulse repetition frequency shall be in the range from 0,2 Hz to 5 Hz. The pulse duration and the pulse repetition frequency of the auditory danger signal shall not be identical with the pulse duration and the pulse repetition frequency of a periodically varying ambient noise in the signal reception area.

NOTE The emergency evacuation signal is a special danger signal. All other danger signals should differ significantly in their temporal pattern from the emergency evacuation signal.

8.3.2 *Temporal distribution of the frequencies*

Auditory danger signals whose pitch varies with time are also suitable (e.g. a high-frequency warble tone or a sequence of sounds with different pitch).

8.4 Duration of the auditory danger signals

Temporary masking by ambient noise of the auditory danger signal 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 auditory danger signal complies with the requirements of **5.1** and **5.2** for a period of at least 2 s. The temporal characteristics of the auditory danger signal should depend on the duration and type of the danger.

9 Required information on sound sources for auditory danger signals

Manufacturers and agents of sound sources for auditory danger signals shall present 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 level $L_{S,\,A\,1m}$ measured in the freefield at a distance of 1 m from the sound source in the main direction of radiation;

b) the maximum value of the octave band level $L_{S,\,oct,\,1m}$ at a distance of 1 m in the main direction of radiation;

c) a sound spectrum showing the levels of partial tones, measured in 1/3 octave or narrow bands within the range from basic frequency to at least 6 000 Hz, at a distance of 1 m in the main direction of radiation. When varying frequency is used corresponding spectra for at least lowest and highest pitch should be presented.

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Annex A (informative)
Example for the calculation of the effective masked threshold according to clause 7

Table A.1 — Calculation of the level of the masked threshold for a given octave spectrum

Number of octave band n	Octave band centre frequency f in Hz	Octave level of ambient noise $L_{N,\,oct}$ in dB	Intermediate value $L_{T_{n-1}} - 7{,}5$ dB	Octave level of masked threshold[1] $L_{T_{n',\,oct}}$ in dB
1	125	60	60	60
2	250	70	52,5	70
3	500	58	62,5	62,5
4	1 000	71	55	71
5	2 000	60	63,5	63,5
6	4 000	52	56	56

[1] The higher value of the octave level of ambient noise and the intermediate value.

Annex B (informative)
Examples of warning signals

In the following examples full lines are used for the signal spectra, broken lines for the ambient noise spectra, and dotted lines for the masked threshold where it differs from the noise spectrum.

Example 1:

Auditory danger signal indicating approaching shuttle conveyer

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

Characteristics of the ambient noise: not varying in time;

level of ambient noise: $L_{N,\,A} = 78$ dB

Selected auditory danger signal: $L_{S,\,A} = 84$ dB

Characteristics of the auditory danger signal: electro-acoustically generated, intermittent signal;

duration signal on ≈ 1 s

duration signal off ≈ 1 s

The frequency distribution and the temporal distribution of the auditory danger signal and of the ambient noise clearly differ from each other. The auditory danger signal is within a frequency range of good audibility. The masked threshold is exceeded by more than 10 dB over one octave. The auditory danger signal can thus be easily recognized.

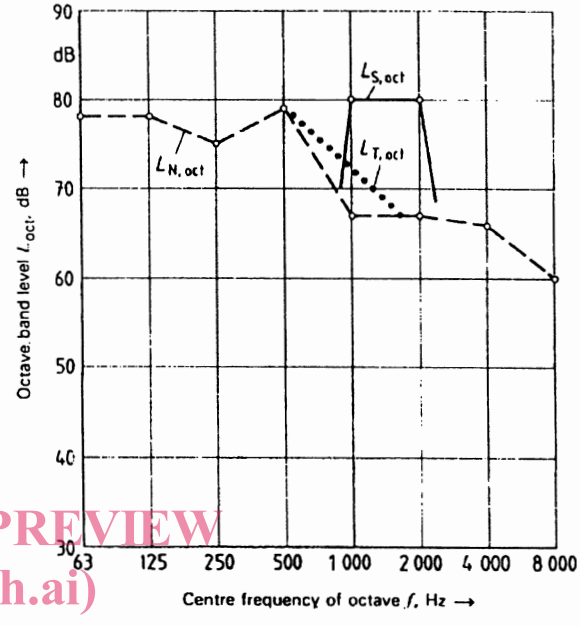

Figure B.1 — Graph displaying the octave band analysis of the ambient noise, the masked threshold and of the auditory danger signal during the "on" period

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Example 2:

Auditory 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: $L_{N,\,A} = 91$ dB

Selected auditory danger signal: $L_{S,\,A} = 100$ dB

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

The auditory danger signal exceeds the ambient noise by more than 15 dB within one octave band; comparable signals do not occur. The auditory danger signal can thus be easily recognized.

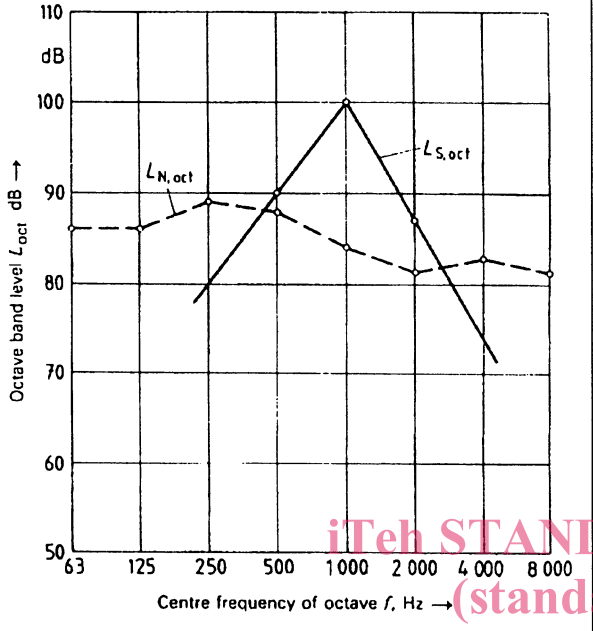

Figure B.2 — Graph displaying octave band analysis of the ambient noise equal to the masked threshold and of the auditory danger signal

Example 3:

Auditory danger signal indicating approaching gantry crane

Ambient noise within the signal reception area:

a) basic traffic noise: $L_{N_1,\,A} = 54$ dB

b) crane noise: $L_{N_2,\,A} = 74$ dB

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 auditory danger signal: $L_{S,\,A,\,S_{max}} = 90$ dB

Characteristics of the auditory danger signal: ringing bell (low repetition frequency bell).

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

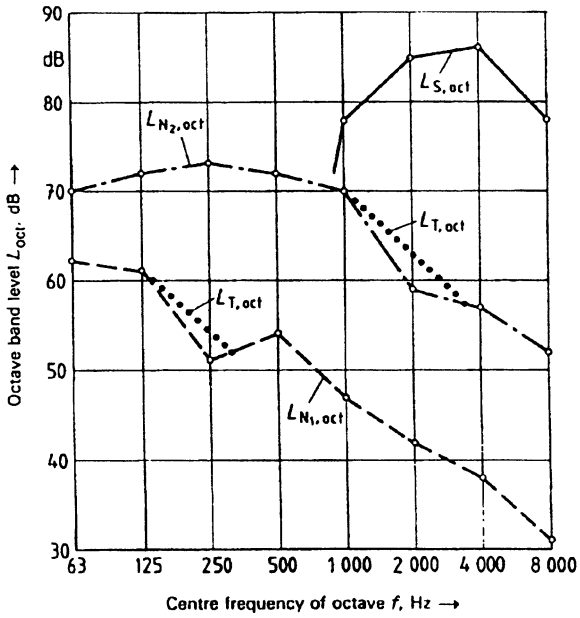

Figure B.3 — Graph displaying octave band analysis of the basic traffic and crane noise, the masked threshold and of the auditory danger signal

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Example 4:

Auditory danger signal used in the area of a conveyor

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

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

Selected auditory danger signal: $L_{S,\,A} = 80$ dB

Characteristics of the auditory danger signal: bell (high repetition frequency).

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Because of the frequencies involved, the difference in noise levels between the auditory danger signal and the ambient noise, and their different temporal distributions, the auditory danger signal can be easily recognized, on condition that there are no other major noise sources.

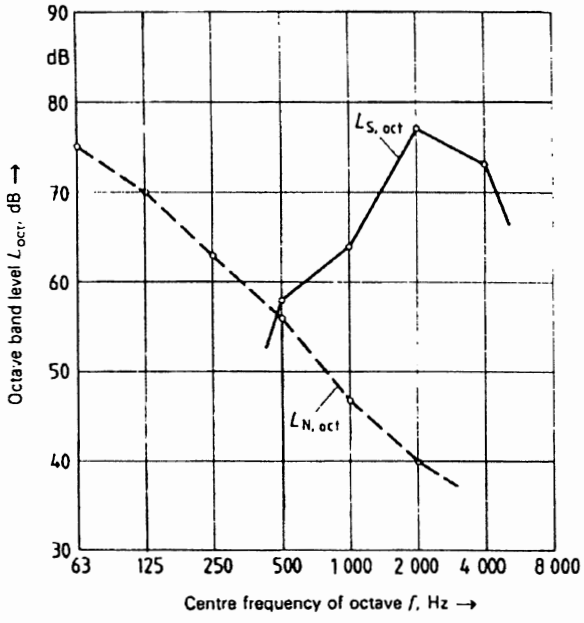

Figure B.4 — Graph displaying octave band analysis of ambient noise equal to the masked threshold and of the auditory danger signal

Example 5:

Auditory danger signal indicating approaching railway track ballast cleaning apparatus within an industrial plant

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

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

Characteristics of the auditory danger signal:

horn signal;

the basic frequency in the 250 Hz band;

duration of each pulse approximately 2 s.

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

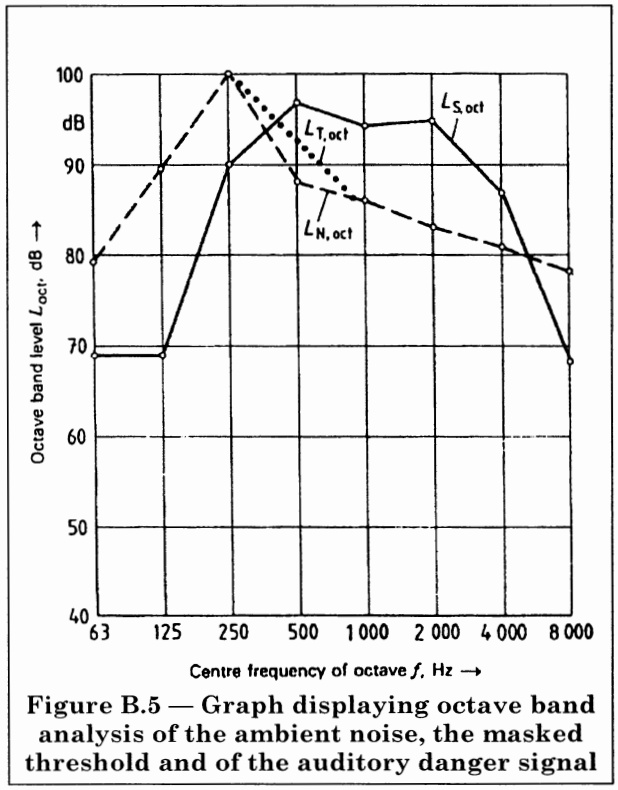

Figure B.5 — Graph displaying octave band analysis of the ambient noise, the masked threshold and of the auditory danger signal

Example 6:

Auditory danger signal of example 5, when a hearing protector is worn

NOTE In cases where hearing protectors are worn the listening check (see 6.2) is preferable to the calculation method since individual sound attenuation is taken into account. Calculation methods are preferable for selecting the type of hearing protector in a specific signal and noise configuration.

A hearing protector for the given ambient noise might have the following mean attenuation values as given in Table B.1.

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

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

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

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

The masked threshold $L'_{T, oct}$ is exceeded by 12 dB in the 2 000 Hz octave band. The auditory danger signal can be easily recognized even by persons wearing the hearing protector.

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