International Standard 7731

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Danger signals for work places — Auditory danger signals

Signaux de danger pour les lieux de travail — Signaux auditifs de danger

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

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Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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Danger signals for work places — Auditory danger signals

0 Introduction

This International 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 and field of application

This International Standard specifies the safety requirements and the corresponding test methods for auditory danger signals for work places in the signal reception area and gives guidelines for the design of the signals. It may also be applied to other appropriate situations.

This International 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 International Standard.

2 References

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

ISO 8201, *Acoustics — Audible emergency evacuation signal.* [1)]

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

IEC Publication 651, *Sound level meters.*

3 Definitions

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

3.1 auditory danger signal: This signal marks the onset and, if necessary, the duration and the end of a dangerous situation.

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

3.2 signal reception area: The 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 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 hearing deficiencies of the listeners as well as the attenuation of hearing protectors.

1) At present at the stage of draft.

4 Symbols

f: centre frequency of a frequency band (e.g. 1/3 octave band).

L_{oct}: octave band level (Reference: 20 µPa).

$L_{N,A}$: A-weighted level of ambient noise in dB.

$L_{N,oct}$: octave level of ambient noise in dB.

$L_{N,1/3oct}$: 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.

$L_{T,oct}$: octave level of masked threshold in dB.

$L_{T,1/3oct}$: 1/3 octave level of masked threshold in dB.

$L_{W,A}$: A-weighted sound power level of the auditory danger signal in dB.

d: sound attenuation of the hearing protectors in dB.

NOTE — In this International Standard, only sound pressure levels (L) are applied.

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 anlysis 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 Discriminancy

At least two of the acoustic parameters of danger signals (sound level, temporal distribution, combination of frequencies) which influence discriminancy 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.

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

6 Test methods

6.1 Acoustic measurements

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

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 Publication 225 and IEC Publication 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 places, 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 or 1/3 octave band levels of the ambient noise.

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

Step 1: In the lowest octave band "1"

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

Step n: ($n > 1$)

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

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

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

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

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

Step n: ($n > 1$)

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

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

NOTE — 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).

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.

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.

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 (ISO 8201) 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.

8.5 Sound level requirement for 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.

Annex

Examples of warning signals

(This annex does not form part of the Standard.)

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

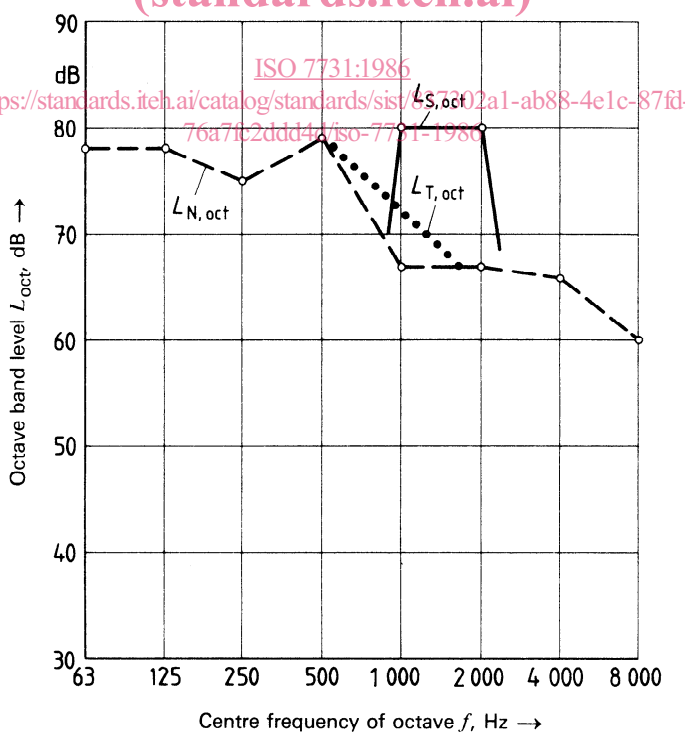

Figure 1 — Graph displaying the octave band analysis of the ambient noise, the masked threshold and of the auditory danger signal during the "on" period

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.

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.

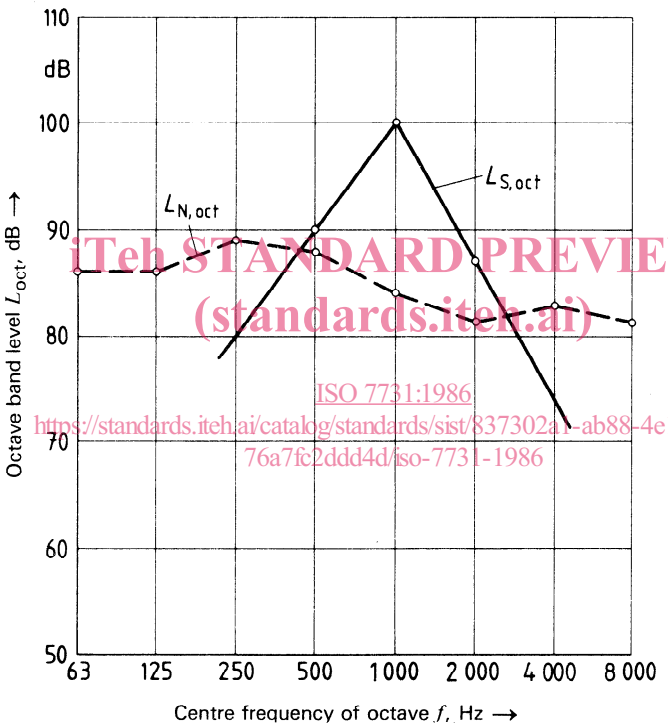

Figure 2 — Graph displaying octave band analysis of the ambient noise equal to the masked threshold and of the auditory danger signal

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.

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: $L_{S, A, Smax.} = 90$ dB

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

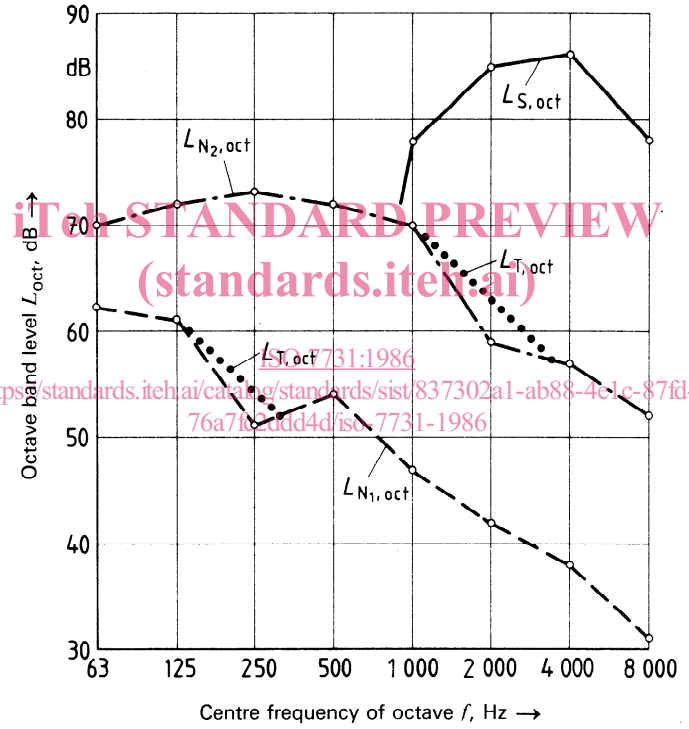

Figure 3 — Graph displaying octave band analysis of the basic traffic and crane noise, the masked threshold and of the auditory danger signal

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 recognized.