INTERNATIONAL STANDARD

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Ergonomic assessment of speech communication —

Part 1:

Speech interference level and communication distances for persons with normal hearing capacity in direct communication (SIL method)

Évaluation ergonomique de la communication parlée —

Partie 1: Niveau d'interférence avec la parole et les distances de communication pour des personnes ayant une capacité d'audition normale en communication directe (méthode SIL)

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Content

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Annexes

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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.

International Standard ISO 9921-1 was prepared by Technical Committee ISO/TC 159, *Ergonomics,* Subcommittee SC 5, *Ergonomics of the physical environment.*

ISO 9921 consists of the following parts, under the general title *Ergonomic assessment of speech communication:*

— *Part 1 : Speech interference level and communication distances for persons with normal hearing capacity in direct communication (SIL method)*

— *Part 2 : Assessment of speech communication by means of the modified articulation index (MAI method)*

— *Part 3 : Speech communication via electroacoustic systems*

Annexes A, B and C of this part of ISO 9921 are for information only.

Introduction

ISO 9921 consists of three parts.

Part 1 describes the assessment of the quality of speech communication, e.g. at workplaces, for persons with normal hearing capacity in direct communication, using the SIL method.

Part 2 describes the modified articulation index (MAI), which permits a more precise prediction than SIL of speech intelligibility in noisy environments, taking into account existing hearing losses and hearing-protector attenuation data.

Part 3 sets safety requirements for indirect speech communication via electroacoustic systems. It gives advice for increasing intelligibility, especially in communication situations such as speech from telephone, loudspeakers, earphones and tape recorders.

Speech communication is influenced by several physical and personal parameters. The quality of speech communication is generally described using speech intelligibility (the percentage of correctly identified verbal test samples) in accordance with ISO/TR 4870.

The following physical parameters should be taken into account:

— sound pressure level, frequency distribution and time pattern of the ambient noise;

— room acoustics (e.g. reverberation time);

— distance between speaker and listener;

— visual contact between the communication partners;

— effects of hearing protectors.

The following personal parameters also should be taken into account :

— the type of speech (speaker's language, dialect and vocabulary);

— listener's knowledge and familiarity with the spoken message [size and selection of vocabulary, group-specific words (e.g. commands), context, semantics];

— effective speech signal (clarity of articulation, vocal effort, speaking rate);

— characteristics of the listener's hearing [hearing capacity, temporary threshold shift, (TTS), directional hearing, overloading];

— listener's and speaker's motivation (expectations, fatigue, stress).

When using an electroacoustic transmission system, additional electroacoustic parameters, such as amplification, frequency response, noise and distortion, will influence the speech communication.

This part of ISO 9921 describes the relation between the speech interference level and the maximum communication distance for persons with normal hearing capacity in direct communication (SIL method). It is based on ISO/TR 3352, and includes additionally communication situations in which different ambient noise levels at the speaker's and listener's positions may occur, where hearing protectors are to be worn, and during which high noise levels will influence the spoken signal and mask its perception. For these extensions and modifications, the current state of knowledge has been taken into account (see annex C).

Additional tools for prediction of speech intelligibility are

— the modified articulation index (MAI) (see future part 2 of ISO 9921); and

— the rapid speech transmission index (RASTI) (in accordance with IEC 268-16).

Ergonomic assessment of speech communication —

Part 1:
Speech interference level and communication distances for persons with normal hearing capacity in direct communication (SIL method)

1 Scope

This part of ISO 9921 provides a method for prediction of the effectiveness of speech communication in the presence of noise generated by machinery (ISO/TR 12100-2) as well as in any other noisy environment. It describes a method for the assessment of direct speech communication with respect to the following parameters:

— ambient noise at the speaker's position;

— ambient noise at the listener's position;

— vocal effort;

— distance between the communication partners.

The physical and personal conditions assumed for this part of ISO 9921 are:

a) Physical conditions:

— reverberation time less than 2 s at 500 Hz;

— direction of speech towards the listener;

— the listener's line of sight arbitrary;

— lip reading not assumed;

— electroacoustic transmission systems excluded;

— no acoustic barrier between speaker and listener.

b) Personal conditions:

— binaural listening;

— normal hearing capacity in accordance with ISO 7029, i.e. medium hearing threshold levels for males up to 70 years of age not exposed to harmful noises (see annex A);

— hearing protectors worn by the speaker;

— neglected influence of hearing protectors worn by the listener (a method which takes into account the wearing of hearing protectors by the listener will be addressed in the future part 2 of ISO 9921);

— speakers and listeners both familiar with the language used and the speech message;

— clear articulation (see ISO/TR 4870);

— speech message consisting of monosyllabic words to represent the worst case.

NOTES

1 Speech intelligibility for monosyllabic words is largely independent of language and semantics.

2 The speech intelligibility reference is 1 000 different monosyllabic words with open test list, in accordance with ISO/TR 4870. For conversion of speech intelligibility from monosyllabic words to sentences, see also ISO/TR 4870.

— decrease in speech intelligibility at high sound levels of speech.

With the conditions and parameters mentioned above, this part of ISO 9921 is applicable to speech communication covering normal conversation, conversation with restricted vocabulary and simple warning shouts or commands. It utilizes the parameters of vocal effort

and speech intelligibility to determine the quality of speech communication.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 9921. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 9921 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO/TR 4870:1991, *Acoustics — The construction and calibration of speech intelligibility tests*

ISO 7029:1984, Acoustics — *Threshold of hearing by air conduction as a function of age and sex for otologically normal persons*

IEC 225:1966, *Octave, half-octave and third-octave band filters intended for the analysis of sounds and vibrations*

IEC 651:1979, *Sound level meters*

IEC 804:1985, *Integrating-averaging sound level meters*

3 Definitions

For the purpose of this part of ISO 9921, the following definitions apply:

3.1 speech communication: Conveying or exchanging of information using voice and hearing modalities.

It involves in particular the hearing and understanding of brief texts, sentences, groups of words and individual words.

3.2 speech intelligibility: Measure of the effectiveness of speech communication.

It characterizes the quality of communication and is usually quantified as the percentage of messages understood correctly.

3.3 vocal effort: Exertion of the speaker, quantified as an A-weighted speech level at 1 m distance from the mouth.

3.4 speech interference level (L_{SIL}): Arithmetic average of sound pressure levels of the ambient noise in the four octave bands with central frequencies 500 Hz, 1 000 Hz, 2 000 Hz and 4 000 Hz (see also IEC 225).

3.5 Lombard effect: Automatic increase in speech level with the increase in ambient noise level.

4 Symbols

For the purposes of this part of ISO 9921, the following symbols apply:

$L_{S, A, 1\,m}$	Equivalent continuous A-weighted sound pressure level, in decibels, of the speech signal at 1 m distance from the speaker's mouth.
$L_{N, A, S}$	Equivalent continuous A-weighted sound pressure level or A-weighted sound pressure level with time response "slow", in decibels of the ambient noise at the speaker's position.
$L_{N, A, L}$	Equivalent continuous A-weighted sound pressure level or A-weighted sound pressure level with time response "slow", in decibels of the ambient noise at the listener's position.
$L_{S, A, L}$	Equivalent continuous A-weighted sound pressure level, in decibels of the speech signal at the listener's position.
$L_{N, oct, i}$	Equivalent continuous sound pressure level in octave band i or octave band i sound pressure level with time response "slow", in decibels of the ambient noise at the listener's position.

NOTE 3 In this part of ISO 9921, only equivalent continuous sound pressure levels ($L_{p, eq}$) are used. Therefore these two indices are not included. The symbols used are based on, but not identical with, those in ISO 31-7.

5 Determination of noise parameters

5.1 General

For the speech interference level method, two different noise measurements are carried out:

— at the speaker's position: the A-weighted sound pressure level, $L_{N, A, S}$;

— at the listener's position: the octave band sound pressure level, $L_{N, oct, i}$, or, for an approximation, the A-weighted sound pressure level, $L_{N, A, L}$.

5.2 Equipment for measurement

For measurements of the A-weighted sound pressure levels, at least Class 2 sound level meters in accordance with IEC 651 or IEC 804 shall be used. In addition, for the octave band analysis, a filter set in accordance with IEC 225 shall be used.

5.3 Microphone positions

Measurement of the sound pressure levels shall be made with the microphone located at the position(s) normally occupied by the head of the person concerned, the person being absent.

If it is necessary for the person to be present or for the person to move around, the microphone shall be located at a distance of 0,1 m to 0,3 m from the entrance of the canal of the external ear receiving the higher value.

5.4 Time-averaging

Equivalent continuous sound pressure levels are preferred in this part of ISO 9921. In the case of approximately stable noise, this can be replaced by the average A-weighted sound pressure level with time response "slow".

In situations where highly reliable intelligibility is required, for example when safety is concerned, the maximum sound pressure level of the communication period with time response "slow" shall be employed.

5.5 A-weighted sound pressure level at the speaker's position

The A-weighted sound pressure level $L_{N,A,S,1m}$ shall be determined during noise situations which are typical for the communicating period.

5.6 Speech interference level

For the determination of the speech interference level L_{SIL}, the sound pressure levels in the octave bands 500 Hz, 1 000 Hz, 2 000 Hz and 4 000 Hz shall be measured at the listener's position during noise situations which are typical for the communication period.

The speech interference level L_{SIL} is calculated as the arithmetic mean of the sound pressure levels of the ambient noise in the four octave bands with the central frequencies 500 Hz, 1 000 Hz, 2 000 Hz and 4 000 Hz. Equation (1) defines this relation.

$$L_{SIL} = \frac{1}{4}\sum_{i=1}^{4} L_{N,oct,i} \qquad \ldots (1)$$

If octave band sound pressure level measurements cannot be carried out, L_{SIL} can be approximated by subtracting a value of 8 dB from $L_{N,A,L}$.

$$L_{SIL} = L_{N,A,L} - 8\ \text{db} \qquad \ldots (2)$$

6 Criteria for direct speech communication

6.1 Vocal effort of the speaker

The speaker's vocal effort is described by the equivalent continuous A-weighted sound pressure level of the speech at a distance 1 m from the speaker's mouth.

The vocal effort is influenced mainly by the ambient noise level at the speaker's position. The hatched area in figure 1 gives the variability of the Lombard effect (see 3.5) for different speakers.

A speaker wearing hearing protectors will reduce his vocal effort by about 3 dB compared to the unprotected situation, and when the ambient noise level $L_{N,A,S}$ exceeds 75 dB (use the right side of figure 1). If the noise level does not exceed 75 dB, the influence of hearing protectors is neglected (use the left side of figure 1).

6.2 Speech level at the listener's position

From the speech level at the speaker's position $L_{S,A,1m}$, the speech level at the listener's position $L_{S,A,L}$ may be approximated using equation (3):

$$L_{S,A,L} = L_{S,A,1m} - 20\lg(r/r_0) \qquad \ldots (3)$$

where

r is the distance in metres between speaker and listener;

$r_0 = 1$ m.

Here the decrease in speech level is assumed to be 6 dB per doubling of distance (see also note 5 in 6.3).

6.3 Relation between speech interference level and communication distance (SIL method) for satisfactory speech intelligibility

The parameter determining the speech intelligibility is given by the difference between the speech level $L_{S,A,L}$ and the speech interference level L_{SIL}, both measured at the listener's position. Satisfactory speech communication is ensured if the difference in levels, $L_{S,A,L} - L_{SIL}$, is $\geqslant 10$ dB at the listener's position.

Figure 2 gives maximum distances for satisfactory speech communication in relation to the speech interference level and the speaker's vocal effort (see figure 1).

NOTES

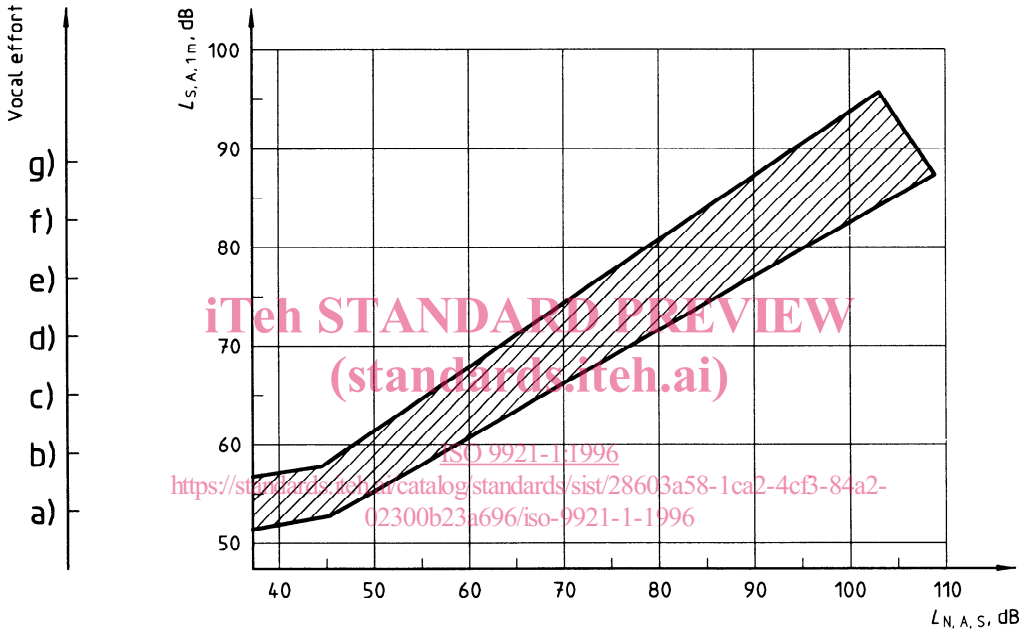
4 For a given level difference, $L_{S,A,L} - L_{SIL}$, very loud or shouted speech is more difficult to understand compared

with speech of lower vocal effort. This effect is taken into account when calculating effective speech level by reducing the speech levels by 1 dB for the vocal effort "very loud", by 3 dB for the vocal effort "shout" and by 6 dB for the vocal effort "maximum shout".

5 The decrease in speech level in figure 2 is assumed to be 6 dB per doubling of distance. This assumption is valid for outdoors and indoors up to distances of about 2 m and, if the reverberation time is less than 2 s at 500 Hz, up to distances of 8 m.

6.4 Additional assessments of the quality of speech communication

In order to evaluate the quality of speech communication, the vocal effort of the speaker and the speech intelligibility of the listener are taken into consideration. The vocal effort of the speaker is given by the speech level at 1 m (see figure 1), its assessment is presented in table 1.



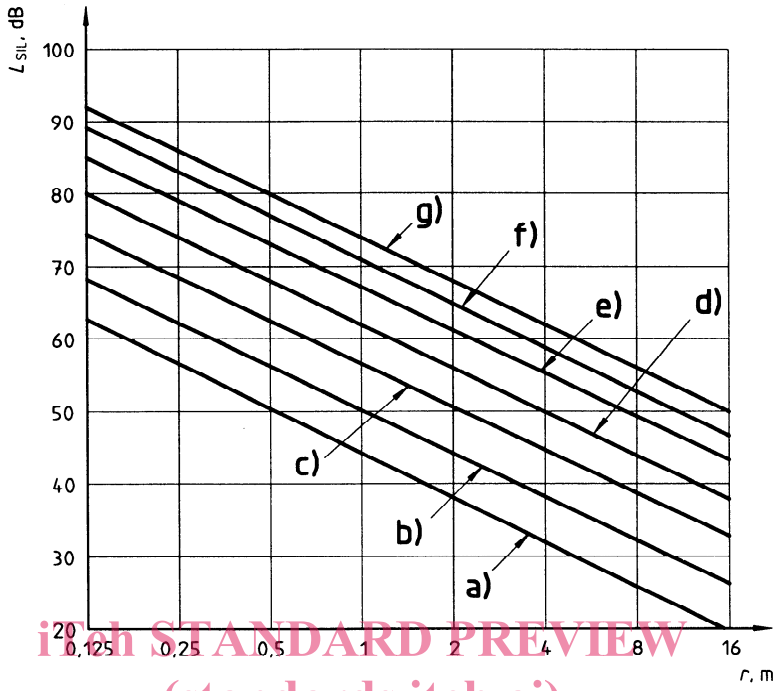
a) Relaxed
b) Normal
c) Raised
d) Loud
e) Very loud
f) Shouting
g) Maximum shout

NOTES

1 Examples of how to use figure 1 are given in annex B.

2 Results shown are summarized from [7], [8], [10], [14], [16] and [17] (see annex C).

Figure 1 — Relation between the range of vocal effort, equivalent continuous speech sound level $L_{S,A,1\,m}$ and the ambient noise level $L_{N,A,S}$ at the speaker's position (Lombard effect)



a) Relaxed
b) Normal
c) Raised
d) Loud
e) Very loud
f) Shouting
g) Maximum shout

NOTE — Examples of how to use figure 2 are given in annex B.

Figure 2 — Relation, for seven levels of speaker vocal effort, between speech interference level L_{SIL} for satisfactory speech communication and maximum distance r between the speaker and listener

Table 1 — Vocal effort of the speaker and its assessment

Vocal effort	$L_{S,\,A,\,1\,m}$	Assessment
Maximum shout	90	Insufficient
Shout	84	Unsatisfactory
Very loud	78	Sufficient
Loud	72	Satisfactory
Raised	66	Good
Normal	60	Very good
Relaxed	54	Excellent