BS EN ISO 24504:2016

BSI Standards Publication

Ergonomics — Accessible design — Sound pressure levels of spoken announcements for products and public address systems (ISO 24504:2014)

bsi.

National foreword

This British Standard is the UK implementation of EN ISO 24504:2016. It is identical to ISO 24504:2014.

The UK participation in its preparation was entrusted to Technical Committee PH/9/-/1, Ergonomics of the physical environment.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

ISBN 978 0 580 90124 9

ICS 13.180

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 June 2016.

Amendments issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN ISO 24504

June 2016

ICS 13.180

English Version

Ergonomics - Accessible design - Sound pressure levels of spoken announcements for products and public address systems (ISO 24504:2014)

Ergonomie - Conception accessible - Niveaux de pression acoustique des annonces vocales pour les produits et systèmes de sonorisation (ISO 24504:2014)

Ergonomie - Barrierefreie Gestaltung - Schalldruckpegel von gesprochenen Ansagen für Produkte und öffentliche Lautsprecheranlagen (ISO 24504:2014)

This European Standard was approved by CEN on 27 May 2016.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

European foreword

The text of ISO 24504:2014 has been prepared by Technical Committee ISO/TC 159 “Ergonomics” of the International Organization for Standardization (ISO) and has been taken over as EN ISO 24504:2016 by Technical Committee CEN/TC 122 “Ergonomics” the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2016, and conflicting national standards shall be withdrawn at the latest by December 2016.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Endorsement notice

The text of ISO 24504:2014 has been approved by CEN as EN ISO 24504:2016 without any modification.

Contents

Page

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 159, *Ergonomics*, Subcommittee SC 5, *Ergonomics of the physical environment.*

Introduction

Today, people conduct their daily lives along with spoken announcements from various products such as home electrical appliances, information and telecommunication products, office-automation equipment, heating equipment, toys, sanitary equipment, and health care products. Some products use spoken announcements to provide instructions in indoor and outdoor public areas such as ticket vending machines, elevators, and escalators. Public address systems are often installed to provide spoken announcements. Such announcements can be indistinct to listeners because of hearing loss that can occur with ageing or because of ambient noise in the surroundings.

This International Standard specifies methods for determining an appropriate sound level range of spoken announcements so that all listeners, including people with age-related hearing loss, can hear them properly against ambient noises. This sound level range specification was determined based on results of experiments in which people of different ages participated. Spoken announcements for which sound pressure levels are within the range specified in this International Standard are expected to be audible and comfortably loud for most users in the presence of ambient noise.

This International Standard is intended to be applied as necessary to products depending on the product type and its conditions of use. It does not apply to spoken announcements used for evacuation or emergency purposes.

ISO 9921 specifies recommended levels of speech-communication quality necessary for conveying comprehensive messages in different applications. Therefore, ISO 9921 differs from this International Standard.

This International Standard adopts the principles of accessible design from ISO/IEC Guide 71, which are amplified in ISO/TR 22411.

INTERNATIONAL STANDARD ISO 24504:2014(E)

Ergonomics — Accessible design — Sound pressure levels of spoken announcements for products and public address systems

1 Scope

This International Standard specifies methods to determine an appropriate sound pressure level range for spoken announcements in environments where ambient noise is less than 80 dB. The specified methods follow the concepts of ISO/IEC Guide 71 and includes consideration of older persons with decreased hearing ability to determine sound pressure levels of spoken announcements. The spoken speech levels that are specified in this International Standard are for products and public-address systems. To improve the accessibility and usability of products, spoken announcements must not only be audible but also presented at comfortable speech levels.

The target products that present spoken announcements are consumer products such as electronic home appliances, information and communication technology services, and products providing services for general users in public facilities indoors and outdoors such as train stations, airports, meeting rooms, amusement parks, and fairs.

This International Standard is not applicable to products providing private information such as automated teller machines in public spaces.

This International Standard is applicable when a loudspeaker producing a spoken announcement is located a short distance from the user in an environment where the sound pressure level with a standard frequency weighting A of ambient noise does not exceed 80 dB. This International Standard is applicable to spoken announcements that are audible to persons with normal hearing for their age when presented by a target product under quiet and anechoic conditions. This International Standard is applicable for both recorded voice and synthetic speech announcements.

This International Standard does not specify sound pressure levels of spoken announcements for systems with automatic sound pressure level control to compensate for fluctuating ambient noise levels. This International Standard is not applicable to spoken announcements heard through headphones or earphones, or to spoken announcements heard with the ear close to the speech sound source, such as in ear speakers specified in IEC 60268-7. This International Standard considers only the audibility of speech and not the process of speech understanding.

This International Standard does not specify the sound pressure levels of spoken announcements presented in emergency situations such as signals for fire alarms, gas leakage, and crime prevention; those are covered in ISO 7240-16 and ISO 7240-19. This International Standard does not specify the sound pressure levels of spoken announcements in automobiles; those are covered in ISO 15006.

NOTE 1 A spoken announcement presented in a repetitive manner from a product such as electronic home appliance is presumed to be heard as an auditory sign but not as a message and is therefore usable with a lower sound pressure level of the spoken announcement than this International Standard specifies.

NOTE 2 It is known that the word recognition performance of native speakers of the language of the announcement is better than that of non-native speakers.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 389-1, *Acoustics — Reference zero for the calibration of audiometric equipment — Part 1: Reference equivalent threshold sound pressure levels for pure tones and supra-aural earphones*

ISO 1996-1, *Acoustics — Description, measurement and assessment of environmental noise — Part 1: Basic quantities and assessment procedures*

ISO 3382-2:2008, *Acoustics — Measurement of room acoustic parameters — Part 2: Reverberation time in ordinary rooms*

ISO 8253-1, *Acoustics — Audiometric test methods — Part 1: Pure-tone air and bone conduction audiometry*

IEC 60050-801, *International Electrotechnical Vocabulary — Chapter 801: Acoustics and electroacoustics*

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

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

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-801, IEC 60268-16, and the following apply.

3.1
spoken announcement
message presented by a live human voice, a synthesized voice, or a recorded/digitized human voice

3.2
ambient noise
sound other than the sound to be measured as a signal

Note 1 to entry: For this International Standard, spoken announcements are regarded as signals.

3.3
speech transmission channel
acoustic and/or electro-acoustic signal path between a source of a signal and a user

3.4
speech transmission index
STI
metric with values 0 through 1 representing the transmission quality of speech with respect to speech intelligibility by a speech transmission channel

[SOURCE: IEC 60268-16]

3.5
simplified STI
metric with values 0 through 1 representing the transmission quality of speech with respect to speech intelligibility by a speech transmission channel calculated only with octave-band sound pressure level difference between the sound pressure level of spoken announcements and sound pressure level of ambient noise based on STI specified in IEC 60286-16

Note 1 to entry: Simplified STI does not account for effects of reverberation.

3.6
speech level
sound pressure level with a standard frequency weighting A or octave-band equivalent sound pressure level of a spoken announcement

3.7
signal-to-noise ratio
S/N
sound pressure level of a signal measured relative to ambient noise

3.8
minimum speech level
speech level with a standard frequency weighting A at which a listener can achieve audibility

3.9
maximum speech level
speech level with a standard frequency weighting A at which half of the listeners feel that the spoken announcement is too loud

3.10
audibility
extent to which the words of spoken announcements are recognizable by listeners

3.11
hearing threshold level
HTL
sound pressure level of a sound at which a person gives a predetermined percentage of correct detection responses on repeated trials minus the reference equivalent threshold sound pressure level

Note 1 to entry: It applies to a specified signal and specified manner of signal presentation under specified conditions according to ISO 8253-1. The reference equivalent threshold sound pressure level shall be in accordance with ISO 389-1.

3.12
pure tone average
PTA
average in decibels of hearing threshold levels of specified frequencies

3.13
reverberation time
T
duration required for the space-averaged sound energy density in an enclosure to decrease by 60 dB after the source emission has stopped

Note 1 to entry: The reverberation time is expressed in seconds.

4 Symbols

Symbols used in this International Standard are presented below.

$L_{N,A}$ sound pressure level of ambient noise with a standard frequency weighting A, in decibels, as measured using the method specified in Annex A

$L_{N,i}$ an octave-band sound pressure level of ambient noise in band *i*, in decibels, as measured using the method specified in Annex A

$L_{S,A}$ speech level with a standard frequency weighting A, in decibels, as measured using the method specified in Annex A

$L_{S,i}$ an octave-band sound pressure level of spoken announcements in band *i,* in decibels, as measured using the method specified in Annex A

T_i a transmission index of octave band *i*, presented as a metric rating between 0 and 1

I STI or simplified STI calculated as a weighted average of T_i from 125 Hz to 8 kHz octave bands

5 Range of sound pressure level of spoken announcements

5.1 General

This International Standard specifies the sound pressure level range of spoken announcements without consideration of reverberation and distance between a signal source and a listener.

The range of the sound pressure level of spoken announcements shall be determined with a minimum speech level and a maximum speech level. The minimum speech level for older users is higher than that for young users, as presented in Annex B. The minimum speech level shall be set to maintain the audibility of spoken announcements considering older listeners with otologically normal hearing for their age. The maximum speech level shall be set to avoid annoyance of listeners with the spoken announcement. Because of their greater hearing sensitivity in general, the speech level for younger adults is used to set the limit used in this International Standard because they are expected to perceive discomfort at lower levels than older adults.

Usually, a mean speech level is 55 dB to 75 dB at 1 m distance from a talker.[8]

When a spoken announcement with a fixed sound pressure level is used, the level shall be adjusted to fall between the minimum and the maximum speech levels, as calculated according to this International Standard.

When the sound level is controllable by users, the level shall be variable to cover a part of the specified range in this International Standard. Audible distortion of spoken announcement from a loudspeaker should be avoided to choose the speech level range for a product.

NOTE It is useful to indicate a speech level range determined by this International Standard at or around the volume control function using a device such as a volume knob, button, or slider.

The A-weighted sound pressure level method is the simplest method, but it has limitations. It shall not be applied in the case of noises that are predominantly low-frequency noises or when ambient noise has a dominant tonal component. In such cases, the effect of ambient noise will not be estimated correctly. The simplified STI method, which is based on STI specified in IEC 60286-16, is applicable for broadband noise both with and without dominant narrow band components. This method is more accurate than the A-weighted sound pressure level method.

NOTE 1 Under circumstances in which the required conditions for both methods listed above cannot be followed, the STI method described in Annex D according to IEC 60268–16 is useful.

NOTE 2 To ascertain the appropriate sound pressure level range of spoken announcements for a product, the level of noise that is typical in the operating environment of the product can be used.

5.2 Criteria to determine the speech level

The required speech level for comfortable listening to spoken announcement is 55 dB which minimizes listening difficulty for younger adults in quiet conditions.[9]

The required signal-to-noise ratio used to determine the minimum speech level for older adults can be estimated using information provided in Annex B. Typical older listeners require a 5 dB signal-to-noise ratio, which corresponds to an STI of 0,65, or better for the best understanding of a clearly spoken single word in an anechoic condition under ambient noise. The difference of required S/N improvement for older listeners from younger listeners is varied from 2 dB to 6 dB among languages. It depends on the PTA difference between younger and older listeners.

The maximum speech level shall be determined by following 5.4. Younger adults have better hearing sensitivity than older adults in general. Because they are expected to perceive discomfort at lower levels than older adults, the level for younger adults is used to set the limit used in this International Standard.

5.3 Relevant factors related to speech perception

Sound reflections are expected to have a detrimental effect on speech perception. A method of STI in IEC 60268-16, Annex L is the standardized method, by which one can predict the detrimental effect of sound reflections. This method uses reverberation time, room volume of the space and distance between a signal source, and a listener to predict STI. To adapt the criteria of STI 0,65 in a closed or a semi-closed space, relevant factors shall be considered when the space is reverberant and/or the quality of a spoken announcement is inferior.

Another factor is the effect of phonetic characteristics of speech for different languages. Annex B presents results of variation of a word recognition test conducted in six countries. The difference of mean scores between different languages for young listeners is approximately 5 dB.

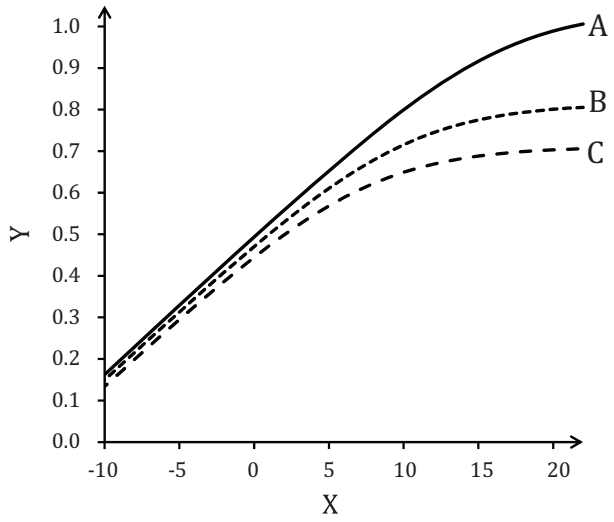
For consumer products that present messages or instructions to users, users are assumed to be physically near the product at the time the messages or instructions are presented. For the simulation method of STI standardized in IEC 60268-16, Annex L, 2 m of distance between a signal source to the users will meet the criteria 0,65 of STI under a typical reverberant environment when the signal-to-noise ratio is 5 dB to 10 dB.

Figure 1 presents the typical relation between the signal-to-noise ratio and STI with distance of 2,0 m. At distances greater than 2 m, sound reflections might detrimentally affect speech transmission under reverberant conditions.

This International Standard shall be used for distances equal to or less than 2 m between a signal source and a listener. The record of measurement conditions and results shall be noted. Examples of the record of measurement conditions and results are presented in Annex C.

NOTE 1 In a free field, where reverberation does not exist, the source-receiver distance is highly variable. Reverberation need not be considered.

NOTE 2 The typical reverberation time of an elementary school classroom (dimensions: 8 m × 8 m × 3 m) is 0,45 s.



Key

X S/N

Y STI

A anechoic space (T = 0,1 s)

B normal space (T=0,34 s)

C reverberant space (T=0,55 s)

Figure 1 — Relations between S/N and STI for three reverberation times for room volume of 192 m^3 with distance 2,0 m

5.4 A-weighted sound pressure level method to determine the speech level

The range of the sound pressure level of the spoken announcements determined using the A-weighted sound pressure level measurement described in Annex A shall be as specified below:

a) Minimum speech level (Lower end of $L_{S,A}$)

The minimum speech level, which is the lower end of $L_{S,A}$, shall be determined using the procedure below.

1) Measure $L_{N,A}$ and ensure that $L_{N,A}$ is less than 80 dB.

2) The lower end of $L_{S,A}$ shall be set to allow, $L_{S,A} - L_{N,A}$ at 10 dB.

3) The minimum lower end shall be 55 dB when the lower end does not exceed 55 dB as a result of the setting in 1).

NOTE Increasing the sound pressure level of the octave band with centre frequency of 8 kHz to increase $L_{S,A}$ should be avoided.

b) Maximum speech level (Upper end of $L_{S,A}$)

The maximum speech level, which is the upper end of $L_{S,A}$, shall be determined using the procedure below.

1) Measure $L_{N,A}$ and ensure that $L_{N,A}$ is lower than 80 dB.

2) The upper end of $L_{S,A}$ shall be 75 dB plus 0,2 times $L_{N,A}$.

3) The upper end must be 90 dB when the upper end exceeds 90 dB as a result of the setting in 1).

5.5 Simplified STI method to determine the minimum speech level

The minimum speech level using simplified STI shall be obtained with measurement of the octave-band sound pressure level described in Annex A as described below.

a) Calculate $L_{S,i} - L_{N,i}$ with results of measurement of octave-band levels from 125 Hz to 8 kHz band of signal and ambient noise.

b) Calculate T_i, an octave-band transmission index in band i (dB), using Formula (1) with $L_{S,i} - L_{N,i}$.

$$T_i = \frac{L_{S,i} - L_{N,i} + 15}{30} \tag{1}$$

NOTE 1 In the event that T_i values higher than 1,0 are obtained, a value of 1,0 shall be assumed.

NOTE 2 In the event that T_i values less than 0 are obtained, a value of 0 shall be assumed.

c) Calculate I using Formula (2) with T_i. Seven octave-bands with centre frequencies of 125 Hz to 8 kHz were used. Weighting factors and redundancy factors for calculation are presented in Table 1, as described in IEC 60268-16. A value of 1,0 shall be assumed if an STI value higher than 1,0 is obtained.

$$I = \sum_{k=1}^{7} \alpha_k \times T_k - \sum_{k=1}^{6} \beta_k \times \sqrt{T_k \times T_{k-1}} \tag{2}$$

where

T_k is the modulation transfer index for octave band k;

T_{k-1} is the modulation transfer index for octave band k-1;

α_k is the weight factor for octave band k in Table 1;

β_k is the redundancy factor between octave band k and octave band k+1 in Table 1.

Table 1 — Octave band weighting factors and redundancy factors

Octave band Hz	**125**	**250**	**500**	**1 000**	**2 000**	**4 000**	**8 000**
A	0,085	0,127	0,230	0,233	0,309	0,224	0,173
B	0,085	0,078	0,065	0,011	0,047	0,095	—

d) Confirm that I exceeds 0,65. Increase $L_{S,A}$ and repeat steps 1) through 3) until I would exceed 0,65 if I is lower than 0,65.

NOTE I is expected to be increased 0,1 with the increase of $L_{S,A}$ of 3 dB under typical noise spectra encountered in dwellings.

Annex A
(normative)

Method for measuring the sound pressure level of spoken announcements and ambient noise

A.1 General

This annex specifies a method for measuring the sound pressure level of spoken announcements for determining a range of the sound pressure level of spoken announcements, as specified in Clause 5 for products used in rooms such as homes, offices, and public areas.

A.2 Method

A.2.1 Types of measurement

The following types of measurement shall be performed.

a) Measurement of the A-weighted sound pressure level

b) Measurement of one-octave-band level

A.2.2 Measuring devices

The measuring device shall be as described below.

a) A sound level meter specified in IEC 61672-1.

NOTE An omni-directional free-field type microphone with a microphone amplifier of which specifications for a sound level meter are specified in IEC 61672–1 can be used instead of a sound level meter.

b) Filters specified in IEC 61260 for performing octave-band analysis.

A.2.3 Measurement acoustical conditions of a space and installation of a signal source

Measurements shall be performed in the actual space where a signal is intended to be presented, with a loudspeaker located and installed as it is intended to be used. When a spoken announcement is presumed to be provided in different weather conditions, measurements shall be conducted in necessary conditions. When the ambient noise fluctuates significantly over a longer duration of measuring time, determine the representative situation and describe the noise fluctuation in the report.

EXAMPLE If a signal source such as a KIOSK in a railway station is set near traffic, choosing busy and normal conditions of traffic to measure the ambient noise level is recommended.

A.2.4 Measurement position

a) The microphone of the sound level meter shall be placed at the position where signals are expected to be heard.

b) The microphone of the sound level meter shall be oriented toward the loudspeaker or other device radiating signals of the product at the position that would correspond to the head centre of a listener.

c) The person taking the measurements shall be distant from the microphone to avoid effects of sound reflections from the measurer's own body.

d) When signals are expected to be heard at multiple positions, measurements should be taken at several representative positions including the closest and the farthest possible positions.

A.2.5 Measurement of sound pressure levels

Measurement of the sound pressure levels of the signals and ambient noise shall be performed as described below.

a) Measurement of the A-weighted sound pressure levels

The measurement shall be performed as follows when the measurement method of A-weighted sound pressure levels of spoken announcements is used.

1) The frequency-weighting characteristic of the sound level meter shall be the A-weighting. The time-weighting characteristic shall be F (Fast).

2) Allow the spoken announcements to sound continuously without silence between announcements and measure the equivalent continuous sound pressure level. The measuring time shall be at least 15 s. If the duration time of the spoken announcement is shorter than 15 s, then repeat the spoken announcement continually when the total duration time is more than 15 s. The indicated values shall be inferred as $L_{S,A}$.

3) Stop generation of the signal and measure the equivalent continuous sound pressure level of ambient noise. The measuring time shall be at least 15 s. The indicated values shall be inferred as $L_{N,A}$.

b) Measurement of octave-band levels

The measurement shall be performed as explained below when the measurement method of one-octave-band level is used.

1) The frequency-weighting characteristic of the sound level meter shall be Z-weighting or FLAT. The time-weighting characteristic shall be F (Fast).

NOTE Z-weighting is a flat frequency response of 10 Hz to 20 kHz ± 1,5 dB, as specified in IEC 61672–1.

2) Allow the spoken announcements to sound continuously without silence between announcements and measure the equivalent continuous octave-band sound pressure level. The measuring time shall be at least 15 s. The indicated value of each band shall be inferred as $L_{S,i}$ for band *i*.

3) Stop generation of the signal and measure the equivalent continuous sound pressure level of ambient noise. The measuring time shall be at least 15 s. The indicated values shall be taken as $L_{N,i}$.

Annex B
(informative)

Effects of age-related hearing loss on word recognition

B.1 General

This annex provides information related to the effect of age-related hearing loss on single-word recognition scores as a function of the signal-to-noise ratio. See Reference [11].

NOTE Word recognition is the most difficult task and worst-case scenario to receive verbal information in daily life. Context of a sentence usually provides a better understanding of spoken announcements.

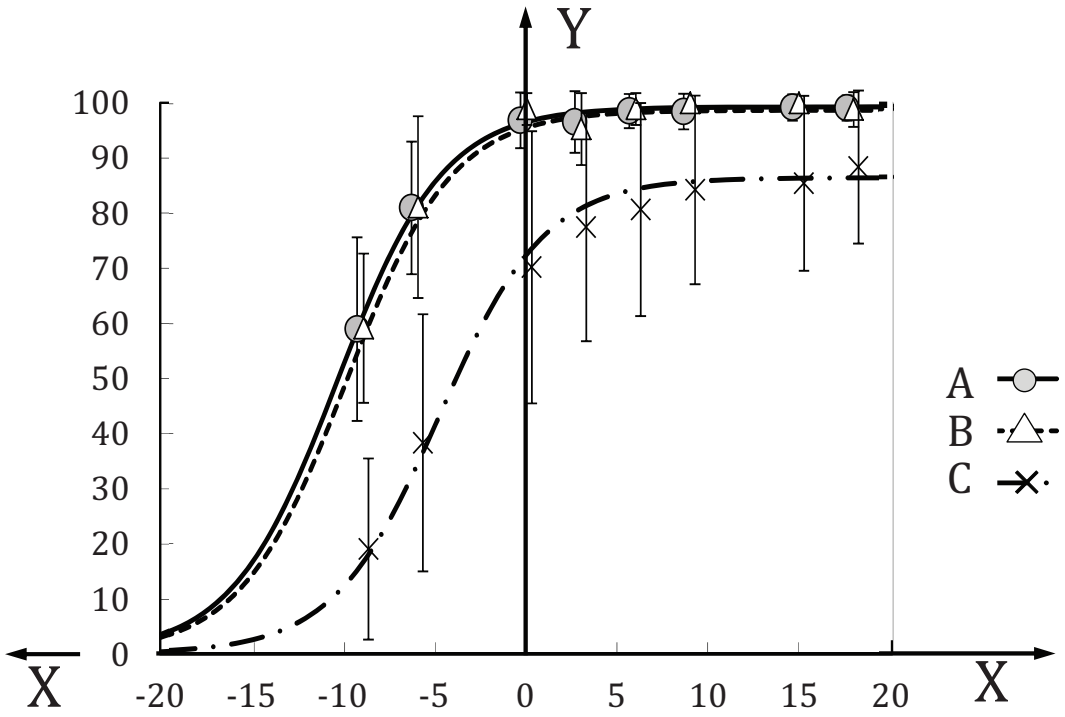
B.2 Relation between word recognition scores, signal-to-noise ratio, PTA, gender, and age

Figure B.1 presents the relation between the signal-to-noise ratio and single-word recognition scores for otologically normal young listeners (20s) and older listeners (aged 60 or older) with various hearing threshold levels.[10] Mean scores and standard deviations for each S/N and each listener group are presented in Figure B.1. The word recognition scores were measured under ambient noise (equivalent continuous sound pressure level with a standard frequency weighting A of 50 dB) with a Hoth spectrum, as specified in.[11] The signal-to-noise ratio was varied according to the presented speech level.

Standardized data of the statistical distribution of hearing threshold levels are published as ISO 1999 and ISO 7029. ISO 1999, Annex B presents hearing threshold levels (HTL) of unscreened listeners from their 30s to 60s. ISO 7029 presents hearing threshold levels of otologically normal people from their 20s to 70s. The hearing threshold level is represented by a Pure Tone Average (PTA), which is the arithmetic average hearing threshold level at 0,5 kHz, 1 kHz, 2 kHz, and 4 kHz, where a signal contributes word recognition.

NOTE Otologically normal persons were defined as “persons in a normal state of health who are free from all signs or symptoms of ear disease and from obstructing wax in ear canals and who have no history of underexposure to noise” in ISO 7029:2000.

For young listeners, a –2,0 dB signal-to-noise ratio is necessary to achieve 95 % of their maximum score. The older listener group with PTA of 23,6 dB requires 5,5 dB improvement of signal-to-noise ratio, on average, under anechoic conditions. Curves are shifted 0,26 dB to a higher signal-to-noise ratio when PTA increases by 1 dB. When a higher level of hearing loss should be considered, estimate the required signal-to-noise ratio with PTA. Scores of middle-aged listeners are not different from those of younger listeners.



Group	Number of subjects (male/female)	Mean age	PTA range	PTA mean
A	34/21	21,3	-5 through 10	2,6
B	1/6	38,5	-2,5 through 10	4,5
C	27/24	70,7	7,5 through 54	23,6

Key

X	signal-to-noise ratio, in decibel
Y	percent correct of word recognition scores
Error bars	standard deviation

Figure B.1 — Word recognition scores and their standard deviation of young (Group A), middle-aged (Group B), and older listener (Group C) groups for each signal-to-noise ratio

Table B.1 presents PTA of otologically normal persons (ISO 7029) and an unscreened population in industrial countries (ISO 1999). The differences of median PTA between screened and unscreened listeners in their 30s to 60s are 3,5 dB for males and 1,5 dB for females, respectively, as ascertained using linear regression between otologically normal and unscreened listeners for each gender.

Considering the population ratio of age and gender for adults in more economically developed countries in Table B.2,[14] the median PTA of an otologically normal person aged 60 or older is assumed as 7,4 dB for the 90th percentile, 14,5 dB for the 50th percentile, and 23,5 dB for the 10th percentile. The PTAs for percentiles respectively correspond to the required improvement of S/N of 1,9 dB, 3,8 dB, and 6,1 dB. S/N of 1,8 dB and 4,1 dB is required to achieve respective results of 95 % of maximum word recognition scores for 50% and 90% of population aged 60 or older, based on a requirement of S/N of –2 dB for young listeners. PTAs of listeners aged 70 or older are regarded as equal to the PTA of 70 years old for this assumption. In fact, a 1,5 dB decline per year of HTL of persons aged 80 or older is known to occur.[15] This decline of hearing capability corresponds to required improvement of S/N of 0,4 dB per year.

Table B.1 — PTA, in decibels, of an otologically normal population (ISO 7029) and an unscreened population in economically developed countries (ISO 1999)

Age years	ISO 7029						ISO 1999					
	Male			Female			Male			Female		
	Fractiles											
	0,9	0,5	0,1	0,9	0,5	0,1	0,9	0,5	0,1	0,9	0,50	0,1
20	−6,8	0,0	9,0	−6,8	0,0	8,8						
30	−6,5	1,3	10,8	−6,3	1,0	10,0	−2,8	4,8	19,0	−4,5	2,8	12,5
40	−5,0	3,8	15,0	−5,3	2,8	13,0	−0,8	8,0	25,8	−3,3	4,3	15,8
50	−2,8	7,8	21,3	−3,5	5,8	17,5	1,0	12,3	29,8	0,5	7,3	22,0
60	0,3	13,3	30,3	−1,3	10,0	24,3	3,0	16,0	39,5	1,5	11,5	30,5
70	4,3	20,5	41,5	1,5	15,0	32,5						

Table B.2 — Population shares of ages and genders for adults among all adults (over 20 years old) in economically developed countries[14]

Age	Male %	Female %
20	9,1	8,8
30	9,1	8,9
40	9,2	9,3
50	8,5	9,0
60	6,2	7,0
70+	5,8	9,1

B.3 Variation of word recognition scores

The differences of word recognition performance between younger and older listeners who are native speakers were measured to validate the target value of this standard internationally. Subjects from six countries participated: China, Germany, Korea, Japan, Thailand, and the United States of America.

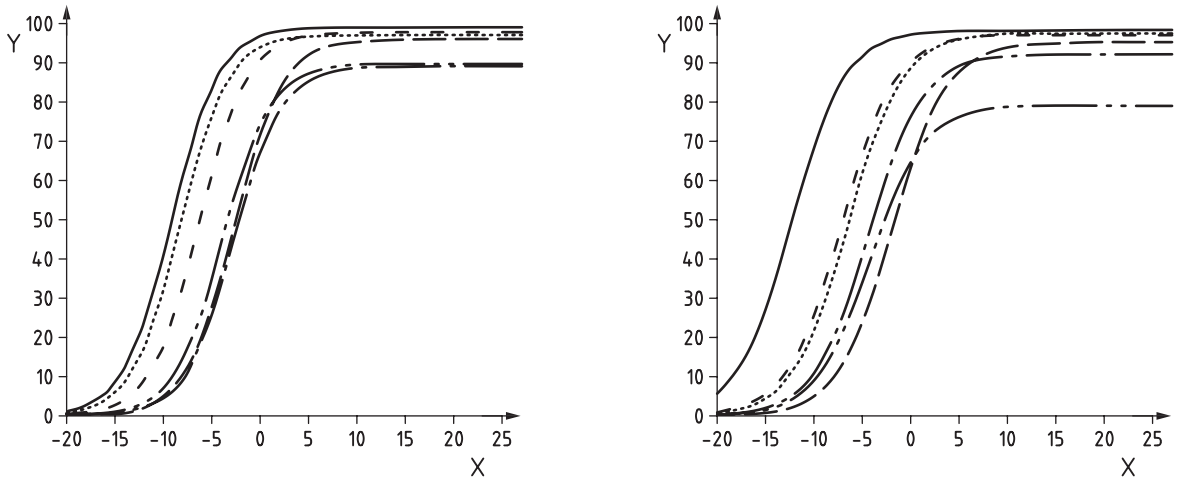
Word recognition tests for all native languages were prepared in the same manner. A target word is embedded in the following sentence in their language: "The next word is the ***target word***, write that down." More than twenty younger listeners in their 20s and more than twenty older listeners over 60 years old participated in word recognition tests for their own respective languages. All participants were selected randomly (unscreened) from those who did not report hearing problems. Hoth spectrum noise[11] with 50 dB in the sound level with a standard frequency weighting A was used as the masking noise. A-weighted signal-to-noise ratios were set from −20 dB to 24 dB in 4 dB steps. Each participant listened to 16 words for each signal-to-noise ratio for a male and a female voice. Test signals were presented through headphones or loudspeakers.

The scores for young Japanese listeners presented in Figure B.3 are used as the standard curve. It was confirmed that the results obtained using the modified rhyme test in English for young listeners under the same conditions[16] present the same curves as the standard curve. The function used as a standard curve is a psychometric function, as Formula (B.1) shows. The maximum scores (S_{max}) and the $L_{S,A} - L_{N,A}$ at which the score is 50 % (m) of S_{max} are varied to obtain regression curves. The steepness of

the function (s) was fixed as 2,9 dB. The root-mean-square error of the model was 0,34 % against mean scores of a Japanese word recognition test with isolated words.

$$S(L_{S,A} - L_{N,A}) = \frac{S_{max}}{1 + \exp\{(m - L_{S,A} - L_{N,A})/s\}}, \% \quad \text{(B.1)}$$

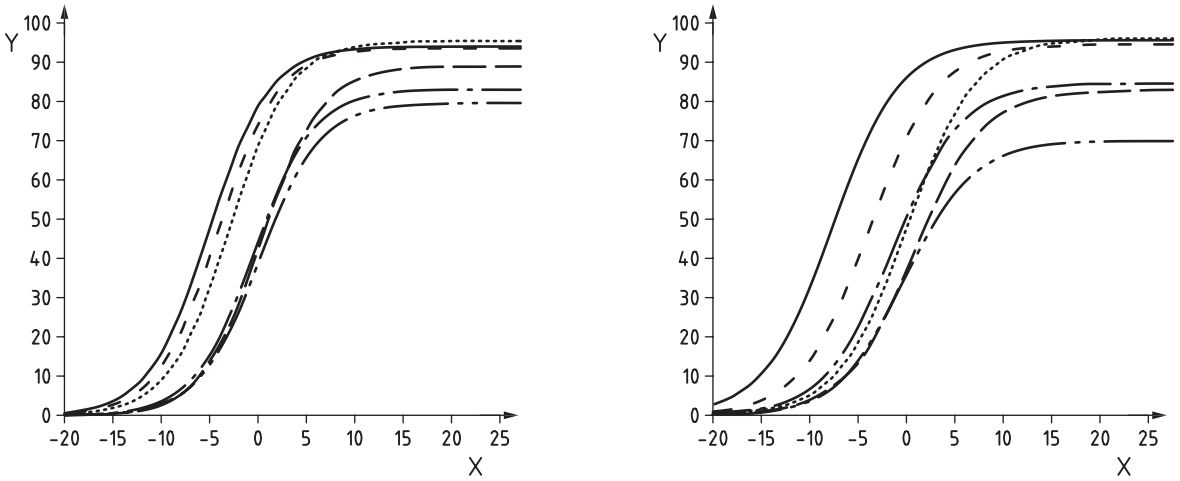
A regression curve for older listeners was also obtained. The difference of $L_{S,A} - L_{N,A}$ between younger and older listeners was calculated to compare differences of word recognition performance between younger and older listeners. The ratio of S_{max}, which is the value S_{max} of older listeners, was divided by that of young listeners for each language. The correlation coefficient of the regression curve and measured data for each language and the gender of the talker was greater than 0,99.



Key

X	signal-to-noise ratio, in decibel
Y	percent correct of word recognition scores
———	Japanese
— · — · —	English (United States of America)
— · — · —	German (Germany)
— — — —	Korean
– – – – –	Chinese (Mandarin)
— — —	Thai

Figure B.2 — Relation between word recognition scores and signal-to-noise ratio for young listener groups in six languages of male voice (left panel) and female voice (right panel)



Key

X	S/N, in decibel
Y	percent correct of word recognition scores
———	Japanese
—··——··—	English (United States of America)
—·——·——·—	German (Germany)
— — — —	Korean
– — – — – —	Chinese (Mandarin)
— — —	Thai

Figure B.3 — Relation between word recognition scores and signal-to-noise ratio for older listener groups in six languages of male voice (left panel) and female voice (right panel)

B.4 Required improvement of signal-to-noise ratio for older listeners

The difference of $L_{S,A} - L_{N,A}$ between younger and older listener groups for each language is presented in Table B3.

The difference of $L_{S,A} - L_{N,A}$ between younger and older listener groups presents the required improvement of the signal-to-noise ratio for older listeners compared to those for younger listeners. The mean difference of languages for the gender of the talker is 3,3 dB. The differences for female voices tend to be greater than those for male voices because female voices have a higher frequency component and because their age-related hearing loss is greater in the higher frequency region. Variations of the differences are caused by the variation of listener age and their hearing ability. The mean differences of PTA between younger and older listeners were measured for three languages, yielding the following results: Chinese 19 dB, Thai 14 dB, and Japanese 17 dB.

Table B3 — Difference of $L_{S,A}$ – $L_{N,A}$ between younger and older listener groups for six languages

Language	Difference of ($L_{S,A} - L_{N,A}$) between younger and older listener groups	
	Male voice	Female voice
Japanese	3,9	4,4
English (American)	3,8	3,6
German	2,1	2,4
Korean	2,7	2,2
Chinese	5,1	6,1
Thai	2,0	2,8

Annex C
(informative)

Examples of measurement condition and result records

C.1 General

Measurement conditions and results should be recorded as appropriate. This annex presents an example of a measurement record.

a) Measurement date and location

EXAMPLE Measurement date: day, month, year

Measurement location: XX Co. Ltd., model room XX

b) Product and model number

EXAMPLE Product and model number: microwave oven, model number XX-XXXX

c) Measurement device and model number

EXAMPLE Measurement device and model number: sound level meter, model number XX; one-third-octave-band analyser, model number XXXX-XX

d) Measurement position

EXAMPLE Measurement position of auditory signal: The microphone was located at the position shown in Figure X, in relation to the product.

e) Apparent noise source

EXAMPLE Noise source: sound of water of the sink in a kitchen. Water flow, XX L/min

f) Ambient noise, measuring method of sound pressure level

EXAMPLE Measuring method of sound pressure level of signals and ambient noise: measurement using octave-band analysis.

g) Measurement results of sound pressure level of spoken announcement and ambient noise

1) $L_{S,A}$ or $L_{S,oct}$

2) $L_{N,A}$ or $L_{N,oct}$

EXAMPLE Sound pressure level of ambient noise: $L_{N,A}$ = 51 dB

C.2 Example of recording sheet

Measurement conditions and results should be recorded on a sheet. An example is shown in Table C.1.

Table C.1 — Example of a recording sheet

Date		Location						
Product	Name							
	Model Number							
Measurement device	Name							
	Mode number							
Measurement position	Height							
Apparent noise source if it exists	Noise source							
	Distances of noise source from measuring position							
Measurement method	A-weighting or octave-band							
Sound pressure level (A-weighted)	Signal							
	Ambient noise							
Sound pressure level (octave-band)	Band center frequency [Hz]	125	250	500	1k	2k	4k	8k
	Signal							
	Ambient noise							
	Simplified STI or STI							

Annex D
(informative)

STI method to determine minimum speech level

D.1 General

This annex presents a method to determine the minimum speech level using STI under conditions in which effects of reverberation must be considered. The minimum speech level using STI can be determined with the octave-band sound pressure level described in Annex A and the impulse response of speech transmission channel described in this annex in accordance with IEC 60268-16. This method is also applicable under conditions complying with IEC 60268-16.

D.2 Impulse response measurement

The method used for measuring the impulse response of a target speech transmission channel is described as an indirect method or impulse response method in IEC 60268-16, Clause 6 with detailed information.

Measurement of the impulse response shall be conducted in accordance with ISO 18233. Because of the use of impulse response, this method is only applicable to a linear, time-invariant transmission channel.

D.3 Measuring device

The measuring device shall be as described below.

a) A sound level meter specified in IEC 61672-1.

NOTE An omni-directional free-field type microphone with a microphone amplifier, of which the specifications for a sound level meter are specified in IEC 61672–1, can be used instead of a sound level meter.

b) A computer-based signal processing function to derive impulse response in accordance with ISO 18233.

D.4 Measurement space and installation of a signal source

Measurements shall be performed in the actual space in which the speech announcement is intended to be presented, with loudspeakers located and installed as they are intended to be used and under quiet conditions such as fine weather without wind.

D.5 Measurement position

a) The microphone shall be placed at a position where signals are expected to be heard.

b) The microphone shall be placed toward the loudspeaker or other device radiating signals of the product at the position that would correspond to the head centre of a listener.

c) The person taking measurements shall be distant from the microphone to avoid effects of sound reflections from the measurer's own body.

d) When signals are expected to be heard at multiple positions, measurements should be taken at several representative positions including the closest and the furthest possible positions.

D.6 Measurement procedure of impulse response of transmission channel

Measurement of the impulse response of a transmission channel shall be performed as described below.

a) The frequency-weighting characteristic of the sound level meter shall be Z-weighting or FLAT.

b) Inject a measurement signal of the impulse response such as a swept-sine signal to a transducer that radiates spoken announcements.

NOTE Spoken announcements presented from multiple loudspeakers can be measured using this method.

c) Capture the radiated signal at measurement positions.

d) Synchronous averaging shall be done for the captured signal if the measurement room is noisy.

NOTE The necessary number of synchronous average depends on the method used and the ambient noise level. See ISO 18233 for details.

e) Calculate impulse responses from captured signals in accordance with ISO 18233.

D.7 Procedures to determine the minimum speech level with octave-band speech level and STI

The minimum speech level considering effects of reverberation in a target speech transmission channel is obtainable using the following procedures.

a) Calculate $L_{S,i} - L_{N,i}$ using the results of measurements of octave band levels from the 125 Hz to 8 kHz bands of the signal and ambient noise.

b) Calculate the modulation transfer function $\left(m_{k,f_m}\right)$ using Formula (D.1) with measured impulse response and $L_{S,I} - L_{N,i}$ octave-band k is the band including 125 Hz to 8 kHz. Modulation frequency f_m is the centre frequency of 1/3 octave bands from 0,63 Hz to 12,5 Hz, as shown below.

$$m_{k,f_m} = \frac{\left| \int_0^\infty h_k(t)\, e^{-j2\pi f_m t}\, dt \right|}{\int_0^\infty h_k(t)^2\, dt} \cdot \left[1 + 10^{-(L_{s,k} - L_{N,k})/10} \right]^{-1} \quad \text{(D.1)}$$

where

$h_k(t)$ is the impulse response of octave band k;

f_m is the modulation frequency;

$L_{s,k} - L_{N,k}$ is the signal-to-noise ratio in decibels at band k.

c) Correction of modulation transfer functions $\left(m_{k,f_m}\right)$ using auditory masking and absolute speech reception with results of measurements of the octave-band sound pressure levels of both signal and ambient noise should be calculated in accordance IEC 60268-16, Annex A.5.3.

d) Calculate R'_i with corrected modulation transfer functions $\left(m'_{k,f_m}\right)$ using Formula (D.2).

$$(L_{S,i} - L_{N,i})' = 10 \log \left(\frac{m'_{k,f_m}}{1 - m'_{k,f_m}} \right) \quad \text{(D.2)}$$

e) Calculate T_i, an octave-band transmission index in band *i* (dB), using Formula (1) with $(L_{S,i} - L_{N,i})'$ instead of $(L_{S,i} - L_{N,i})$.

f) Calculate *I* using Formula (2) with T_i.

g) Confirm that *I* exceeds 0,65. If *I* is lower than 0,65, then increase $L_{S,A}$ and repeat steps from 1) to 3) until *I* exceeds 0,65.

NOTE *I* is expected to be increased 0,1 with the increase of $L_{S,A}$ of 3 dB under typical noise spectra observed in dwellings.

Bibliography

[1] ISO 9921:2003, *Ergonomics — Assessment of speech communication*

[2] ISO/IEC Guide 71:2001, *Guidelines for standards developers to address the needs of older persons and persons with disabilities*

[3] ISO/TR 22411:2008, *Ergonomics data and guidelines for the application of ISO/IEC Guide 71 to products and services to address the needs of older persons and persons with disabilities*

[4] IEC 60268-7:2010, *Sound system equipment – Part 7: Headphones and earphones*

[5] ISO 7240-16:2007, *Fire detection and alarm systems — Part 16: Sound system control and indicating equipment*

[6] ISO 7240-19:2007, *Fire detection and alarm systems — Part 19: Design, installation, commissioning and service of sound systems for emergency purposes*

[7] ISO 15006:2011, *Road vehicles — Ergonomic aspects of transport information and control systems — Specifications for in-vehicle auditory presentation*

[8] Pearsons K.S., Bennett R.L., Fidell S. Speech levels in various noise environments" (Report No. EPA-600/1-77-025). Washington, DC: U.S. Environmental Protection Agency (1977)

[9] Kobayashi M., Morimoto M., Sato H., Sato H. Optimum speech level to minimize listening difficulty in public spaces. *J. Acoust. Soc. Am.* 2007, **121** (1) pp. 251–256

[10] Sato H., Kurakata K., Mizunami T. Accessible speech messages for the elderly in rooms," Ninth Western Pacific Acoustics Conference Seoul, Korea, 2006

[11] ITU-T P.800. Methods for Subjective Determination of Transmission Quality - Series P: Telephone Transmission Quality; Methods for Objective and Subjective Assessment of Quality (1996)

[12] ISO 7029:2000, *Acoustics — Statistical distribution of hearing thresholds as a function of age*

[13] ISO 1999:2013, *Acoustics — Estimation of noise-induced hearing loss*

[14] Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat. *World Population Prospects*. Revision, 2010

[15] Wiley T.L. Chappell, R., Carmichael, L., Nondahl, D.M., and Cruickshanks, K.J. "Changes in Hearing Thresholds over 10 Years in Older Adults. *J. Am. Acad. Audiol.* 2008, **19** (4) pp. 281–292

[16] Sato H., Bradley J.S., Morimoto M. Using listening difficulty ratings of conditions for speech communication in rooms. *J. Acoust. Soc. Am.* 2005, **117** (3) pp. 1157–1167

[17] ISO 18233:2006, *Acoustics — Application of new measurement methods in building and room acoustics*

This page deliberately left blank

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Copyright in BSI publications

All the content in BSI publications, including British Standards, is the property of and copyrighted by BSI or some person or entity that owns copyright in the information used (such as the international standardization bodies) and has formally licensed such information to BSI for commercial publication and use.

Save for the provisions below, you may not transfer, share or disseminate any portion of the standard to any other person. You may not adapt, distribute, commercially exploit, or publicly display the standard or any portion thereof in any manner whatsoever without BSI's prior written consent.

Storing and using standards

Standards purchased in soft copy format:

- A British Standard purchased in soft copy format is licensed to a sole named user for personal or internal company use only.
- The standard may be stored on more than 1 device provided that it is accessible by the sole named user only and that only 1 copy is accessed at any one time.
- A single paper copy may be printed for personal or internal company use only.

Standards purchased in hard copy format:

- A British Standard purchased in hard copy format is for personal or internal company use only.
- It may not be further reproduced – in any format – to create an additional copy. This includes scanning of the document.

If you need more than 1 copy of the document, or if you wish to share the document on an internal network, you can save money by choosing a subscription product (see 'Subscriptions').

Reproducing extracts

For permission to reproduce content from BSI publications contact the BSI Copyright & Licensing team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email subscriptions@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Useful Contacts

Customer Services
Tel: +44 345 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 345 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

bsi.